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FINAL REPORT

ON

THE DEVELOPMENT OF CONTOURED INTERLOCKING TAPE WOUND TITANIUM ROCKET MOTOR CASES

PART I

DESIGN, METALLURGY AND EXPERIMENTAL FABRICATION

February 15, 1961

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FINAL REPORT

ON

THE DEVELOPMENT OF CONTOURED INTERLOCKING TAPE WOUND TITANIUM ROCKET MOTOR CASES

PART I

DESIGN, METALLURGY AND EXPERIMENTAL FABRICATION

Submitted in Partial Fulfillment of U. S. Army Ordnance Materials Research Office Contract DA-30-069-ORD-3101

J. P. [signature]
Director of Engineering

Wright Aeronautical Serial Report No. MP.00-224

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Curtiss-Wright Corporation
Wright Aeronautical Division
Wood-Ridge, New Jersey

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Design

Experimental Mfg.

Metallurgy

Chief Project Engineer

Manager, Engineering Projects

Chief of Metallurgy

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1.0 INTRODUCTION

The development of pressure vessels for use in solid fuel rocket motor cases has reached a state wherein further progress may be restricted by lack of suitable high strength metals and limitations in methods of fabrication. Though the potentially high strength to weight ratio of fiber reinforced cases is recognized, the use of metallic cases offers certain advantages peculiar to metals alone.

The application of metal wire or tape as reinforcement in pressure vessels dates back at least a century. High-tensile steel wire has been used as the banding material on certain rifles and guns as well as in other hollow bodies (1). With the possible exception of one recent investigation (2, 3) no attempt has been made to utilize the transverse strengths of wire or tape to support the axial stress in pressurized vessels. Valenta (2) describes vessels reinforced with wound profile strip which is shrunk on to a vessel (while simultaneously quenched to high strength), putting the monolithic portion of the vessel into compression. Though the tape is contoured and interlocked, it does not appear to support any of the axial load. The present report describes a means whereby the transverse strength of severely cold reduced tape is fully utilized. The method simultaneously facilitates application of ultra high strength materials which might otherwise be difficult or impossible to use.

The interlocking titanium tape concept is an outgrowth of relatively recent work carried out by this contractor (4) in the development of the high strength titanium alloy B120VCA. In sheet form, this alloy is heat-treatable to a yield strength of 180,000 psi, a strength level which on a strength-to-weight basis is higher than that of the best ferrous materials used in rocket motor casings today. Unfortunately, this alloy is difficult to weld and even a successful weld cannot be heat treated to maximum strength because the aging response of base material and weldment differ considerably. It was observed that this alloy, similarly to most precipitation hardenable alloys, benefits considerably as a result of cold work prior to aging. Thus, the useful strength level of B120VCA can be increased to 300,000 psi, a strength which if fully utilized in a pressure vessel would result in a strength-to-weight ratio of about 1.7×10^6 in.

1.0 INTRODUCTION (Continued)

The objectives of the present contract consisted primarily of the development of fabrication and metallurgical procedures for the manufacture of two basic structural shapes, the development of a wrapping machine and finally the experimental manufacture of two sub-scale vessels. These objectives have been met.

The Curtiss-Wright Corporation wishes to acknowledge financial support from the U. S. Army through the Ordnance Materials Research Office. The assistance of Dr. J. L. Martin, Messrs. G. A. Darcy, Jr. and I. Kahn of that Office as well as of Messrs. R. L. Weatherington and C. H. Martens of the U. S. Army Rocket and Guided Missile Agency is gratefully acknowledged.

2.0 SUMMARY

During the contract period, June 15, 1960 to January 14, 1961, the Wright Aeronautical Division of the Curtiss-Wright Corporation has pursued the work program as originally detailed in the Proposal (5) and has demonstrated the feasibility of interlocked tape wound pressure vessels from both the metallurgical and experimental manufacturing standpoint. Demonstration of the design concept as based on hydrostatic pressure and other environmental tests will be carried out as part of a proposed follow-on to the present contract (6).

"I" beam and channel shapes were designed, fabricated and tested. Turks heading was selected in preference to die drawing, though the latter process might be utilized at a future date for final sizing.

A structural rig for experimental verfication of stress analysis data has been fabricated. Several techniques for precise determination of tape dimensions have been evaluated resulting in the selection of a metallographic method. A specification for B120VCA titanium starting wire has been written and coordinated with two potential sources. The static coefficients of friction of drawn and heat treated tape have been measured and separate interference fit measurements of the interlock have been carried out. The aging response of both shapes in terms of metallographic structure and mechanical properties have been determined and a final heat treatment selected. The low temperature properties of the B120VCA sheet, including notch sensitivity tests have been determined. Several vessel liner materials and bonding methods have been evaluated.

Vessel wrapping apparatus including dummy arbors, collapsible mandrels and other auxiliary apparatus have been designed, manufactured and utilized in the fabrication of two prototype vessels. Design modifications in tape as well as manufacturing techniques based on experience gained in the present program have been carried out and will be incorporated in the proposed follow-on effort.

3.0 RECOMMENDATIONS FOR FUTURE WORK

Limitations inherent in the "Turks Heading" process of wire manufacture, together with observations made both during interference fit testing and wrapping require that the currently used tape shapes be redesigned to incorporate deeper grooves in both shapes. This will assure greater contact area and permit loosening of tolerances on internal corner radii.

Several changes in the wrapping apparatus, collapsible arbor and mandrel removal will be carried out. Presently used 300M steel used in end adapters will be replaced by 25% nickel iron resulting in a higher available yield strength.

The proposed second phase of the present contract will include experimental manufacture of six pressure vessels which will be subjected to hydrostatic tests. The program will further include such studies and analyses relating to adapter attachment, wrapping technique, tape design, metallurgy and other areas found critical during the course of investigation leading to the development of a practical application of the concept.

4.0 DESIGN AND STRESS

4.0 DESIGN

4.1 Mechanical Design

The feasibility of using a high-strength interlocking tape wrapped vessel for a light-weight rocket motor was investigated from a design and stress point of view. Figure 1 shows the selected interlocking tape configuration of three layers. The configurations analyzed were based on a motor I.D. of 6.2 inches and an operating pressure of 4700 psi. This diameter sub-scale vessel was selected because of the availability of a piston rig adaptable to hydrotesting this vessel. In the stress analysis of this vessel, the effects of the small diameter on bending stresses and elastic instability were neglected. This was done to permit direct up scaling to a larger diameter motor.

The design of the interlocking titanium tape is based on a minimum allowable longitudinal and transverse yield strength of 250,000 psi and total (elastic plus plastic) strain of 4% in the transverse direction.

Based on these mechanical properties, two interlocking configurations were studied with emphasis placed on manufacturing feasibility and minimum weight. Figure 2 (b) shows one arrangement with "full-line" contact between adjacent butted channels; and Figure 2 (a) shows another arrangement resulting in "point" contact (under load) between butted channels. Stress analysis has indicated that the full-line butted contact between adjacent channels produces the more efficient arrangement. The final tape dimensions for both the channel and "I" beam are shown in Figure 3.

Additional stress analysis was performed on the inner channel layer in order to determine the local bending stress in each channel caused by the internal pressure (Figure 4). This bending stress is a result of the longitudinal bending of the channel between "I" beam flanges, and adds directly to the longitudinal stress. However, this condition would not arise in a full-scale rocket motor case since the internal pressure for the same tape stress level would be greatly reduced. The present six inch diameter sub-scale test vessel is designed to yield at 4700 psi pressure, whereas a larger diameter vessel would operate at approximately 1000 psi. To alleviate this local bending stress in the sub-scale vessel, the width of the "I" beam flanges was increased from .025 to .040 inches (Figure 5). This reduces the free beam length of the channel and thus reduces the local bending stress.

4.1 Mechanical Design (Continued)

As seen in Figure 3, the legs of the "I" beam and channels are tapered. This is to permit assembly of the wires under the worst tolerance condition. To insure interlocking of the wire assembly, the "I" beams are pre-stressed in the transverse direction. The theoretical load required to force an "I" beam or channel into position is approximately equal to 2500 pounds. This load should be exerted by a roller of 5 inches minimum diameter. The theoretical axial tension required when wrapping either an "I" beam or channel should not exceed 200 pounds. The 2500 pound applied load required to force the wire into position was calculated on the basis of an assumed coefficient of friction between titanium of 0.2 and a roller contact length of .1 inch. A survey of the literature, later confirmed by direct tests, indicated that this value is low and a value of 0.3 is more realistic. The maximum axial load of 200 pounds results in a residual pre-stress of 50,000 psi for the tape in position on the vessel. This assumes that the entire axial winding load remains in the wrapped tape due to friction along the interlocking surface.

4.2 Stress Analysis

Stress analyses of the butted and spaced channel configurations have been completed. When the channel ends are spaced, it is possible to design channels and "I" beams so that only two different tape shapes are required and any number of layers can be added. This situation will occur when

$t_{1A} = t_{1B}$ and $L_D = L_C$. (See Figure 6 for nomenclature). The spacing between the channels will then equal the spacing between the "I" beams. This arrangement is not ideal from a stress standpoint. The loading on the channels produces bending stresses in addition to the axial stresses. This arrangement also results in a varying load distribution across the wall of the vessel which tends to overstress the inside and outside layers while understressing the middle layers. Thus, the efficiency is reduced.

When the adjacent channel ends are butted, two different shapes of tape are sufficient only when n (the number of "I" beams) is equal to 1 (3 layers) or the spacing between the "I" beams is 0. For all other configurations, more than one shape of "I"

4.2 Stress Analysis (Continued)

beam is required. For optimum hoop stress design, it is desirable to have spacing between the "I" beams; therefore, the case where n = 1 is recommended. This case also affords the minimum overall wall thickness. From a stress standpoint, the butted channel arrangement is preferable to the spaced channel arrangement because the channel bending stresses and the varying load distribution across the wall are reduced.

Having established the interlock configuration which yields minimum stresses, an analysis was performed to determine the actual tape dimensions. The butted channel tape configurations were analyzed in detail and the results are shown in Figure 7.

An outline of the stress analysis is given below:

(a) Consideration of the load in the longitudinal direction determines the shank thicknesses of the "I" beam and the channel. Since there are two channel layers sandwiching an "I" beam layer in a three layer vessel, the shank must be twice as thick as the channel shank. This assumes no pre-stressing of the "I" beam at the interlock. However, an initial compressive prestress imposed on the butted channel ends will tend to maintain line-to-line contact and minimize channel bending.

(b) The thickness of the interlocking legs is obtained next. For short interlocking leg heights ($\Delta = 0.010$), the allowable shear stress determines the thickness of the leg. In general, this thickness is more than two and one-half times the channel leg height. Since the interlocking legs are relatively short in height and broad in thickness, the interlocking load was assumed to be transmitted in shear without accounting for bending effects.

(c) The length of the "I" beam must be equal to the sum of twice the channel leg thickness plus twice the "I" beam leg thickness.

(d) The height of the channel leg (Δ) is determined by the allowable bearing stress on the interlocking joints.

4.2 Stress Analysis (Continued)

(e) The length of the channel (Lc) is determined last. The metal-filled area of the wall is varied by varying the channel lengths. For an optimum design, the metal-filled area is sized for the allowable vessel hoop stress.

The detailed stress calculations made in determining the final shapes of the "I" beam and channel are shown in Appendix I.

4.3 Weight Estimates

A weight estimate was made to determine the percent weight saving of the titanium tape over a solid wall steel shell of 300M material having a uniaxial yield strength of 200,000 psi minimum. The weight of the tape wrap includes the interlocking tape and the plastic liner. The weight of the interlocking tape shell is 50% less than the weight of the 300M shell (Figure 8).

4.4 End Attachments

The design for attaching the ends of the interlocking tape to the domes is shown schematically in Figure 9. All three layers of tape, after being wrapped around the threaded dome adapter, are held in place by groove pins. (An investigation of other bonding methods was carried out and is reported in Section 5.) Because of the helical winding of the interlocking tape, the natural tendency of the tape under pressure would be to unwind (See Figure 10). The necessary restraint can be attained in three ways: (1) by bonding the interlocking tapes with an epoxy resin to withstand the shearing tendency to unwind; (2) by using a counter-winding combination of layers in which the unwinding tendencies can be mechanically neutralized; (3) by relying on the interference fit between interlocking tapes to withstand the unwinding tendency through friction. Stress analyses have indicated that the torsional shear stresses are low (422 psi) and the friction between tapes will restrain the vessel from unwinding.

Figure 9 shows the adapter to be tapered where the unsupported cylindrical section of the interlocking tape starts. This taper minimizes the discontinuity stresses at the intersection. Under internal pressure the tapered adapter section in contact with the tape will yield radially outward and reduce the discontinuity effects.

4.4 End Attachments (Continued)

Sealing of the vessel against internal pressure can be accomplished by coating the inside of the motor with a layer of vinyl. Vinyl, which has a relatively low modulus of elasticity, is capable of adhering to the tape wrapped vessel without cracking when subjected to the radial and longitudinal strains of the pressurized vessel.

The final design of the sub-scale vessel is shown in Figure 11. This drawing shows details of the tape, adapters, and the assembly. The piston rig, which is used for hydrotesting, is shown in Figure 12.

4.5 Piston Rig - Jacking Fixture

In order to test the operation of the Piston Rig Apparatus, a burst test of a solid 300M steel vessel was carried out. The vessel was pressurized to a burst pressure of 5000 psi without damage to the piston rig. However, in assembling the piston covers containing the hard rubber "O" rings and leather back-up ring, a larger than expected force was required to compress the "O" ring. This force was transmitted through the vessel to ground. Consequently, a jacking fixture was designed and fabricated which will prevent this high compressive force from being transmitted into the vessel. The design of the jacking fixture is shown in Figure 13.

4.6 Structural Rig

A structural rig which will be used to evaluate the interference fit has been designed and fabricated. The purpose of this rig is to determine the parameters which affect the stresses in the tapes. Schematically shown in Figure 14 is a freebody diagram of the channel subjected to the loads resulting from the interference fit. It may be observed that the interference fit tends to clamp the channel flange and prevent rotation during pressurization. Figure 15 shows the apparatus which will be used to evaluate these stresses. The channel sections are fabricated from B120VCA titanium strip and will be ten times the actual cross-sectional dimensions. The clamping plates will also be fabricated from B120VCA titanium. These plates when bolted together will produce an interference fit with the channel sections. Hoop restraint is induced by transverse clamping which simulates the internal pressure effects. The test procedure to be used for this rig is detailed in Appendix II, and the instrumentation layout is shown in Figure 16.

4.7 Roll Redesigns

The following procedure was used to determine the dimensions of the proper finish "I" beam rolls that would yield the correct tape cross-section. The form rolls were not reworked and are shown in Figure 17. Figure 18 shows the finished rolls assembled, the dimensions of the rolls, and the resulting rolled tape dimensions. Since the angle of 17° is more than the desired 12°, a new roll was made (Figure 19) having an angle of 1 to 3°. This roll produced a tape angle of 7.5°. A plot was then constructed (Figure 20) which relates roll angle to tape angle. Based on this data a new roll was made having angles of 4.5 to 5.5°. The resulting tape dimensions are shown in Figure 21. The "I" beam roll width was also changed to produce a greater interference fit.

A similar procedure was carried out for the redesign of finish channel rolls. The form rolls shown in Figure 22 were also not reworked. The first shape rolled is shown in Figure 23, the second in Figure 24, and the third in Figure 25. A plot of channel roll angle versus tape angle is shown in Figure 26.

TYPICAL WIRE CONFIGURATION

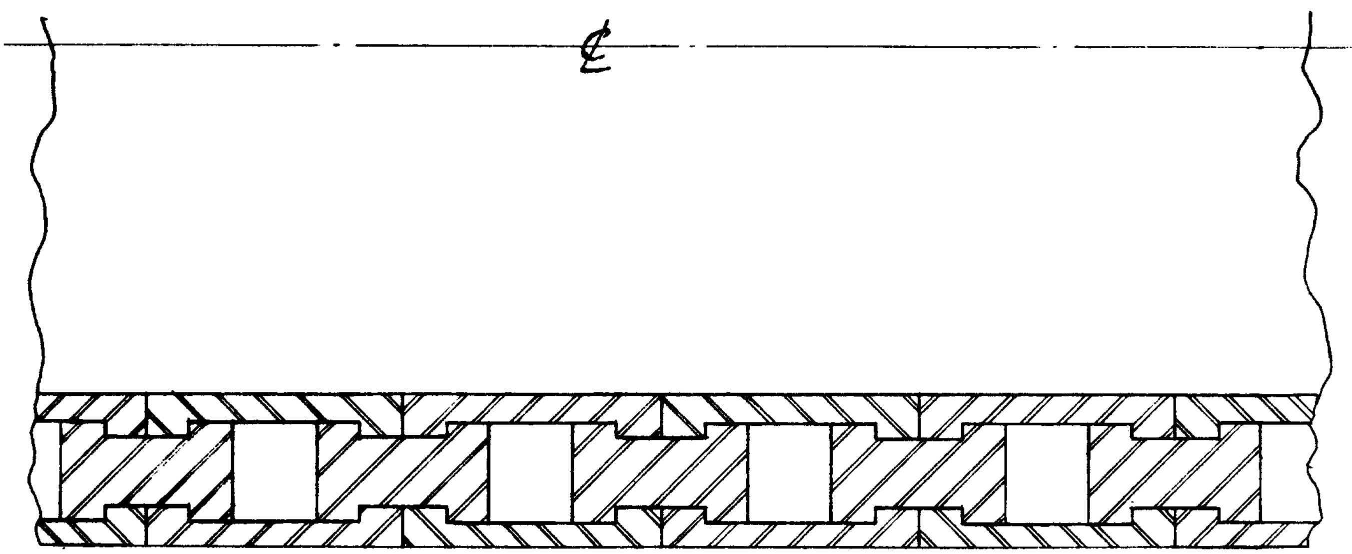
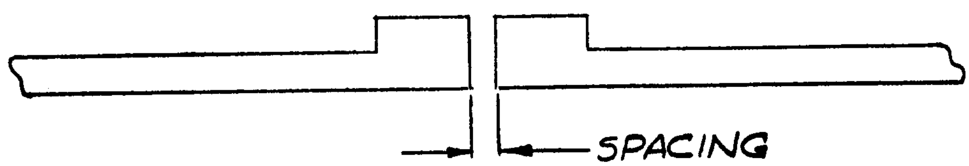


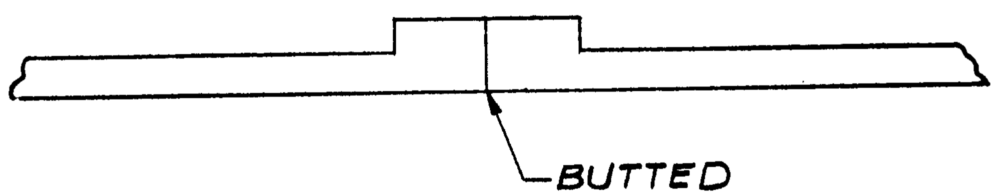
Figure 1

CHANNEL END ARRANGEMENT



CHANNEL ENDS SPACED

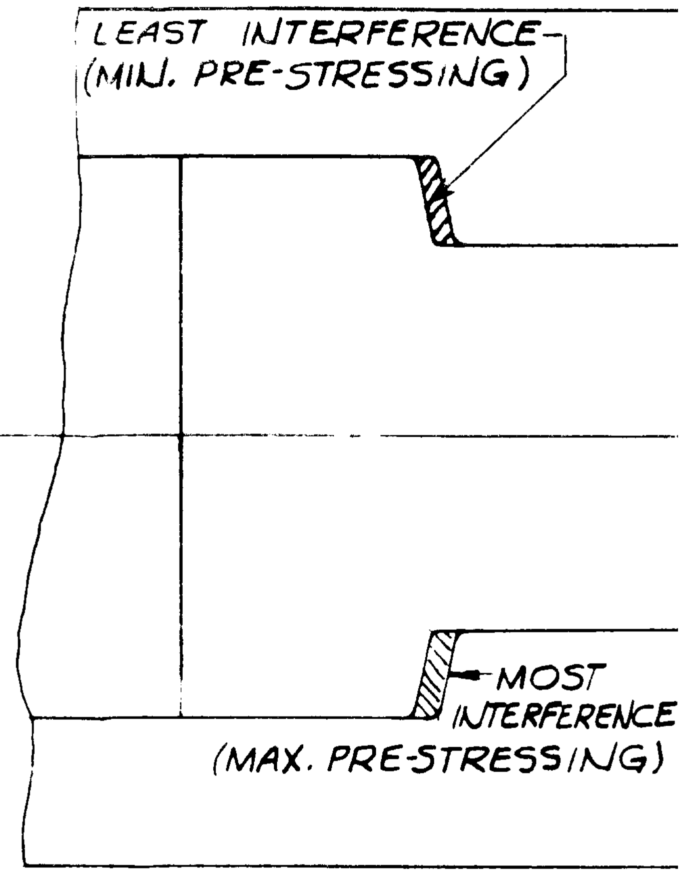
(a)



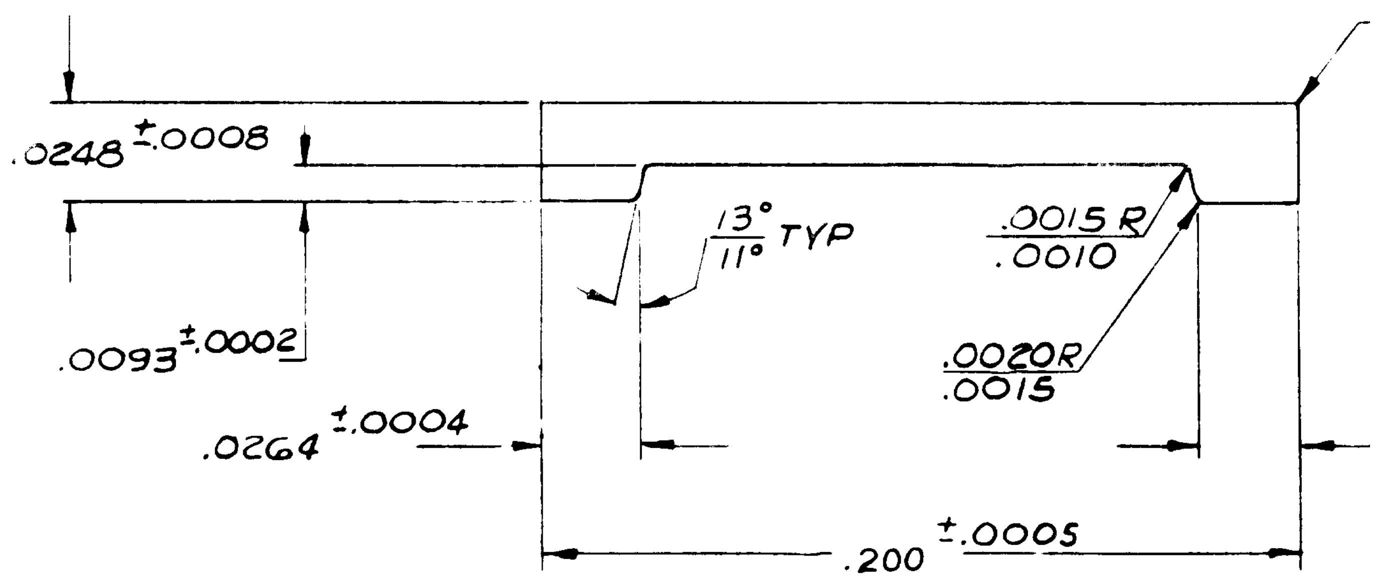
CHANNEL ENDS BUTTED

(b)

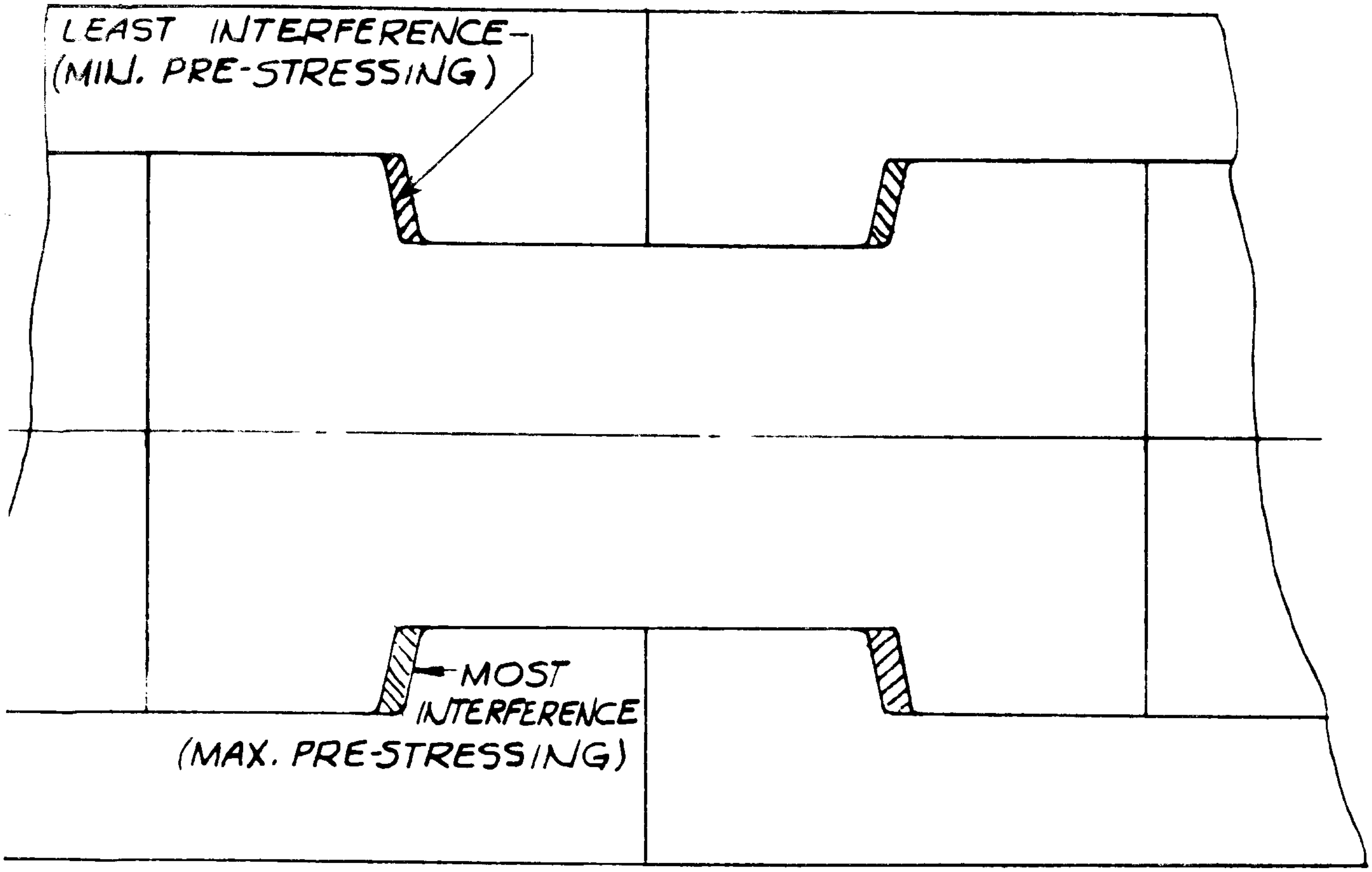
Figure 2



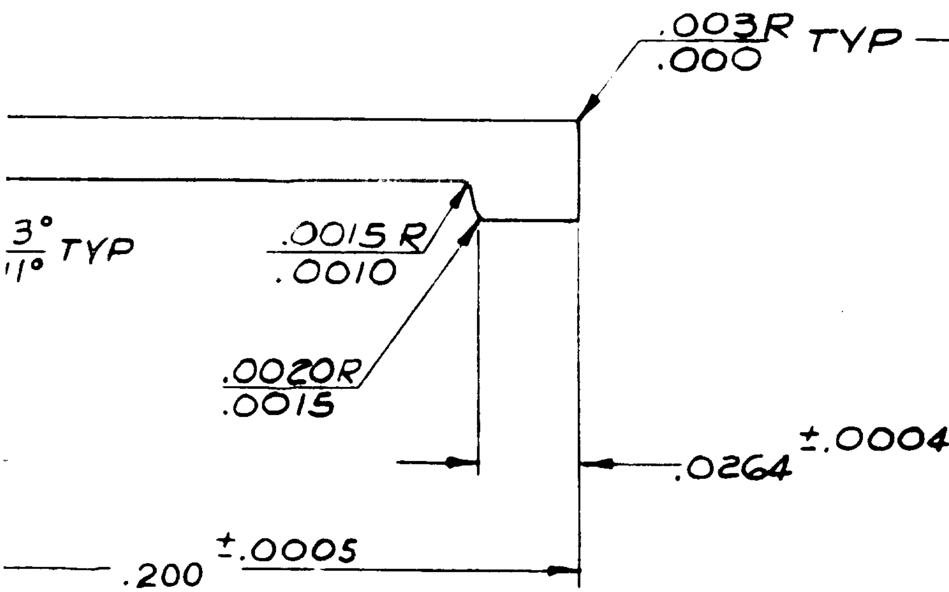
LOCKING W
SCAL



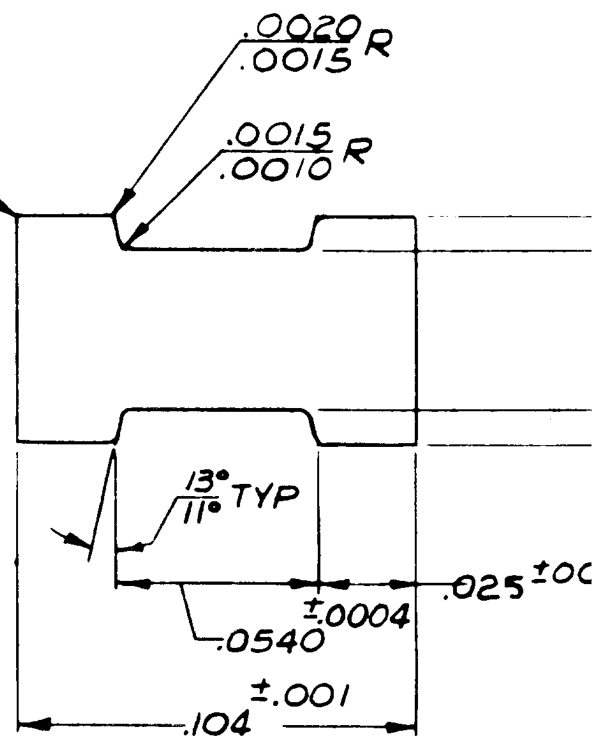
OUTER LOCKING WIRE DETAIL
SCALE 20/1



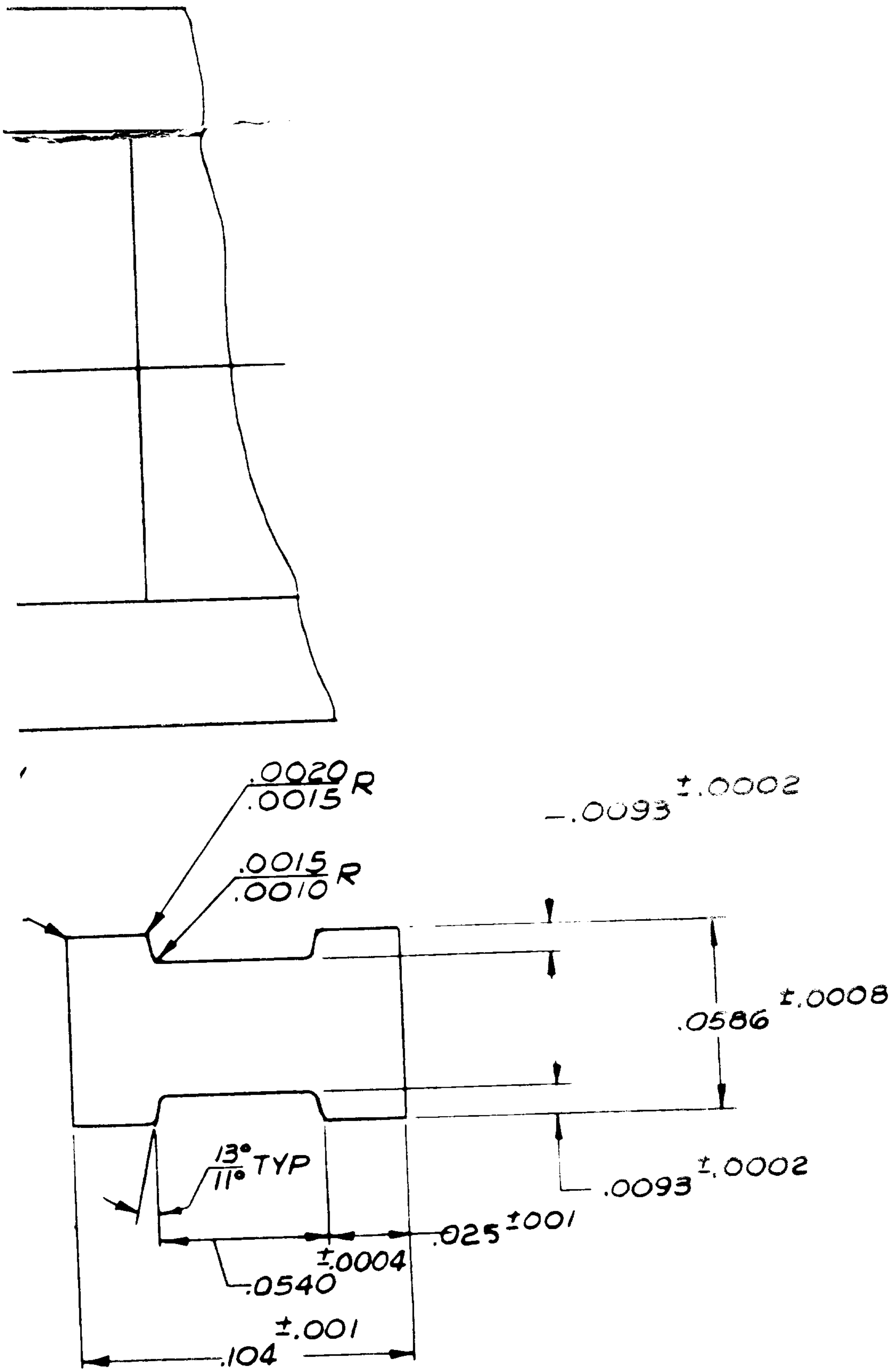
LOCKING WIRE ASSEMBLY
SCALE 50/1



CKING WIRE DETAIL
SCALE 20/1



INNER LOCKING WIRE DETA
SCALE 20/1



ER LOCKING WIRE DETAIL
SCALE 20/1

Figure 3

BENDING STRESS - CHANNEL

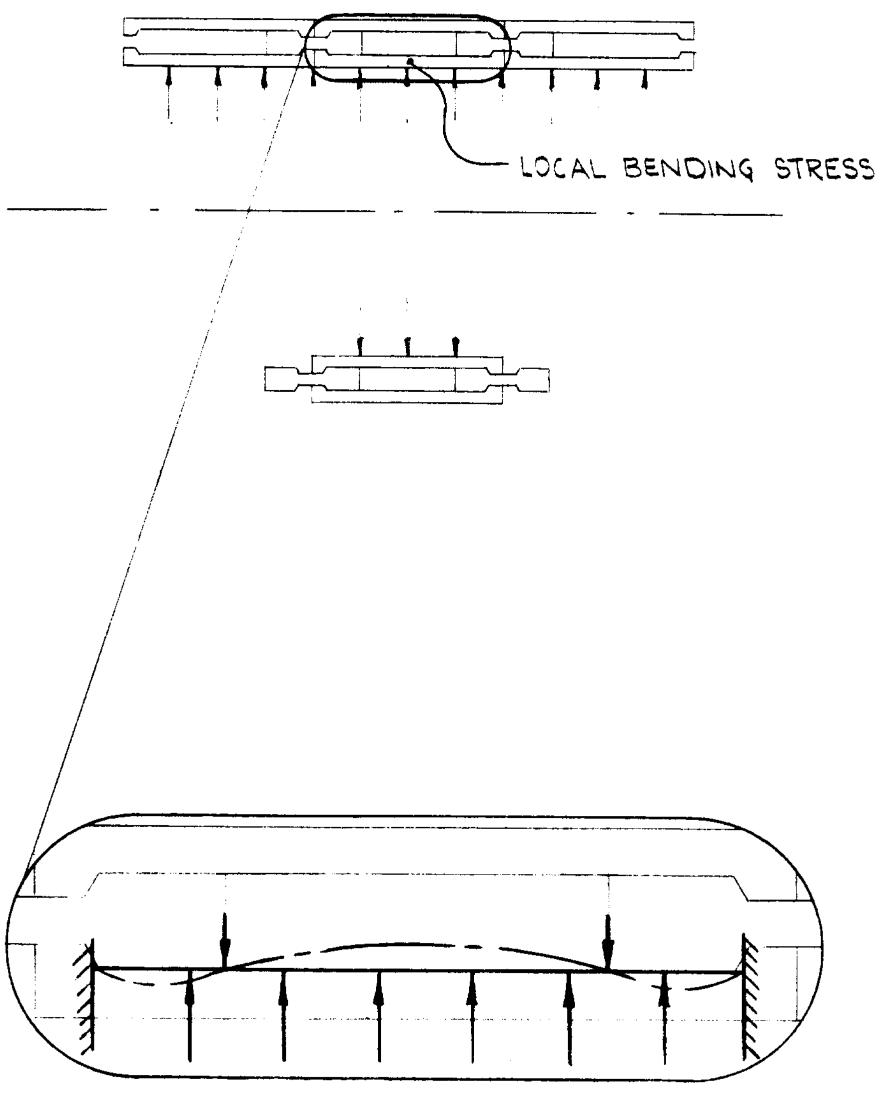
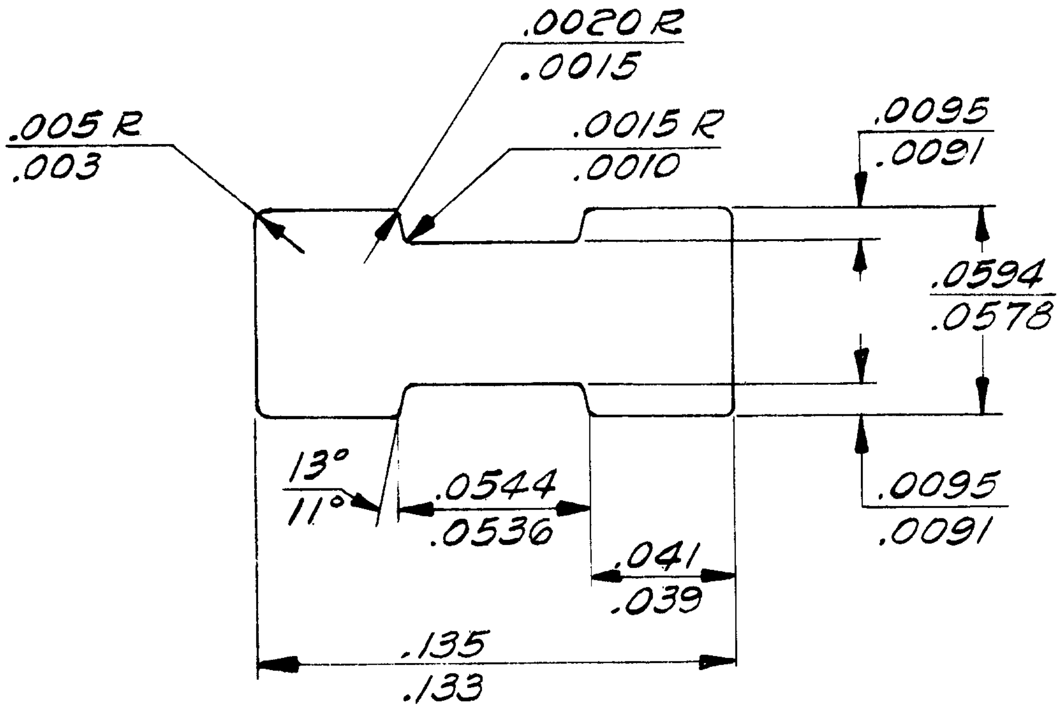


Figure 4



WIRE - I-BEAM

Figure 5

WIRE NOMENCLATURE

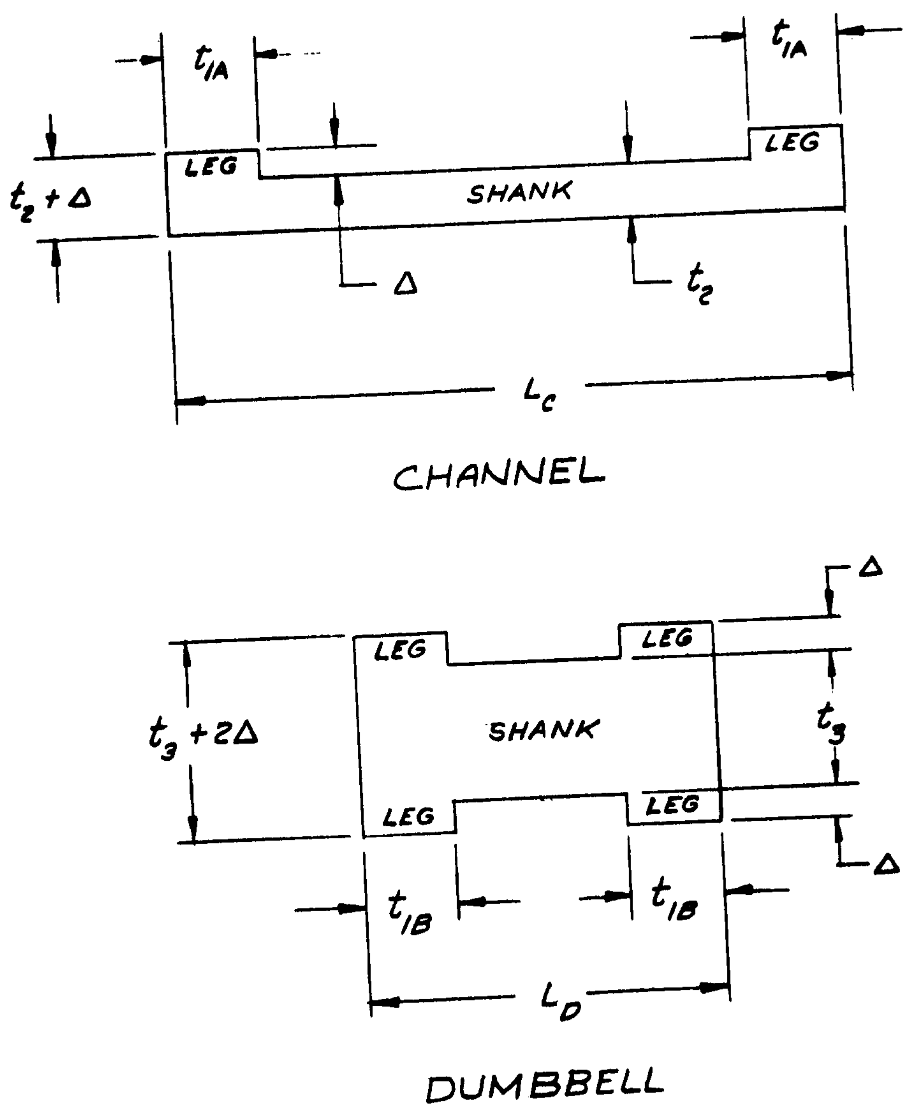


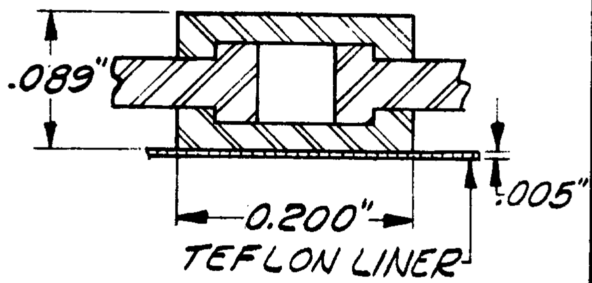
Figure 6

STRESS ANALYSIS SUMMARY

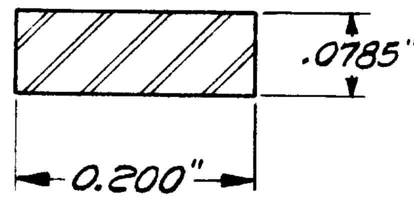
Configuration	3 Layers Butted Channels
Wire Material	Titanium Alloy, B120VCA
Mechanical Properties (psi)	
Longitudinal	250,000
Transverse	250,000
Bearing	417,000
Shear	150,000
Dumbell Dimensions (in.)	
Length - L_D	0.104
Shank Thick. - t_3	0.040
Leg Thick. - t_{1B}	0.026
Spacing - S	0.093
Interlock - $\triangle$	0.0093
Channel Dimensions (in.)	
Length - L_C	0.197
Shank Thick. - t_2	0.0155
Leg Thick. - t_{1A}	0.026
Spacing - S	0
Interlock - $\triangle$	0.0093
Overall Vessel Thickness (in.)	0.089
Helix Angle	0°-46.2'
Dumbell Stresses (psi)	
Hoop	250,000
Axial	250,000
Interlock Bearing	416,000
Channel Stresses (psi)	
Hoop	250,000
Axial	250,000
Leg Bending	0
Leg Shear	150,000
Shank Bending	0
Torsional Shear Stress (psi)	422

Fig. 7

WEIGHT COMPARISON



SEE FIGURE 3 FOR WIRE DIMENSIONS



TITANIUM AT 250,000 PSI Y.S.	TRICENT AT 200,000 PSI Y.S.
CHANNEL (2) = .001269# DUMBELL (1) = .000897 LINER = .000069 .002235#	SHELL = .00453#

WEIGHT SAVING OVER CYLINDRICAL SECTION OF TRICENT MOTOR $= \frac{.00453-.002235}{.00453} = 50\%$

Figure 8

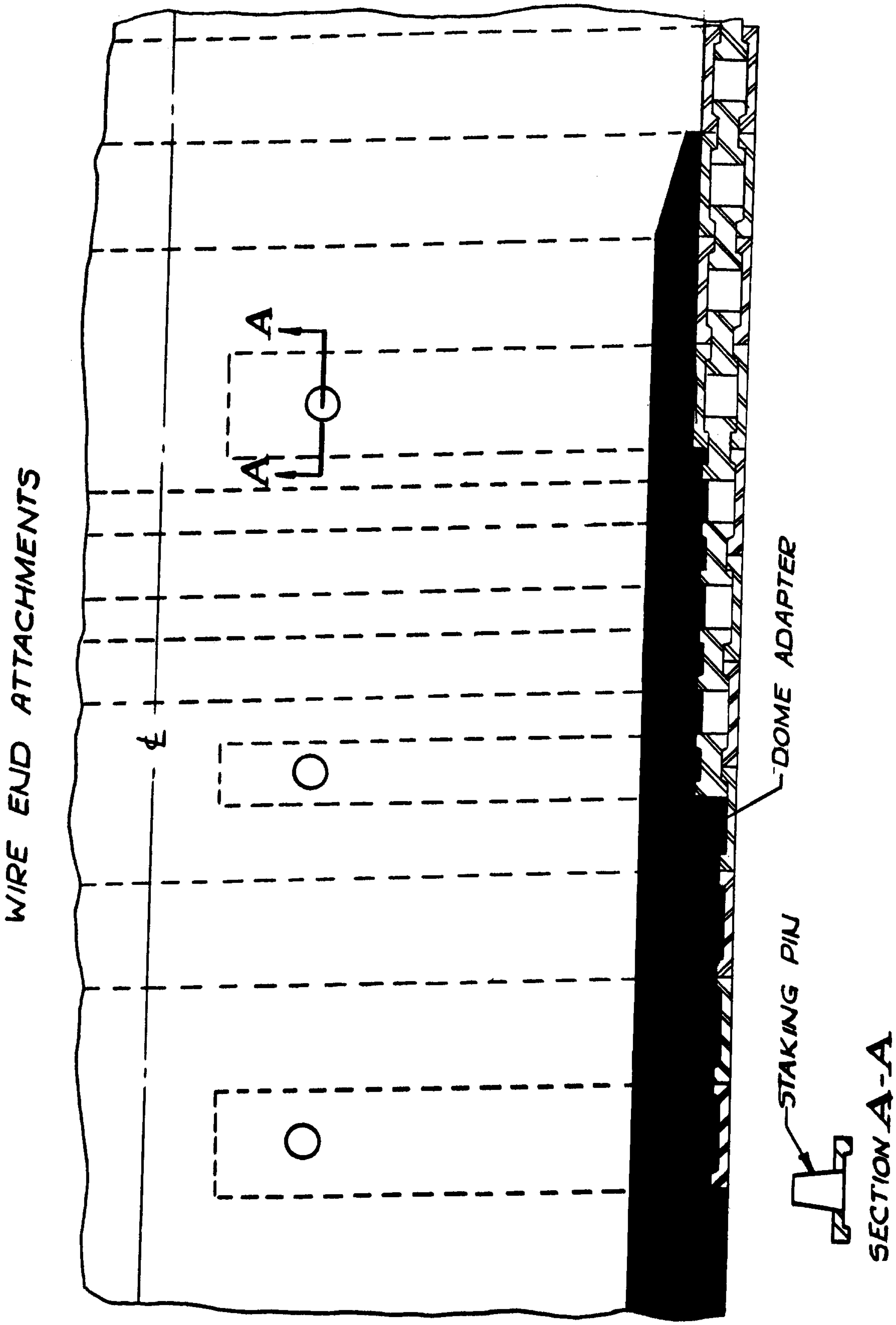

WIRE END ATTACHMENTS
A
A
DOME ADAPTER
STAKING PIN
SECTION A-A

Figure 9

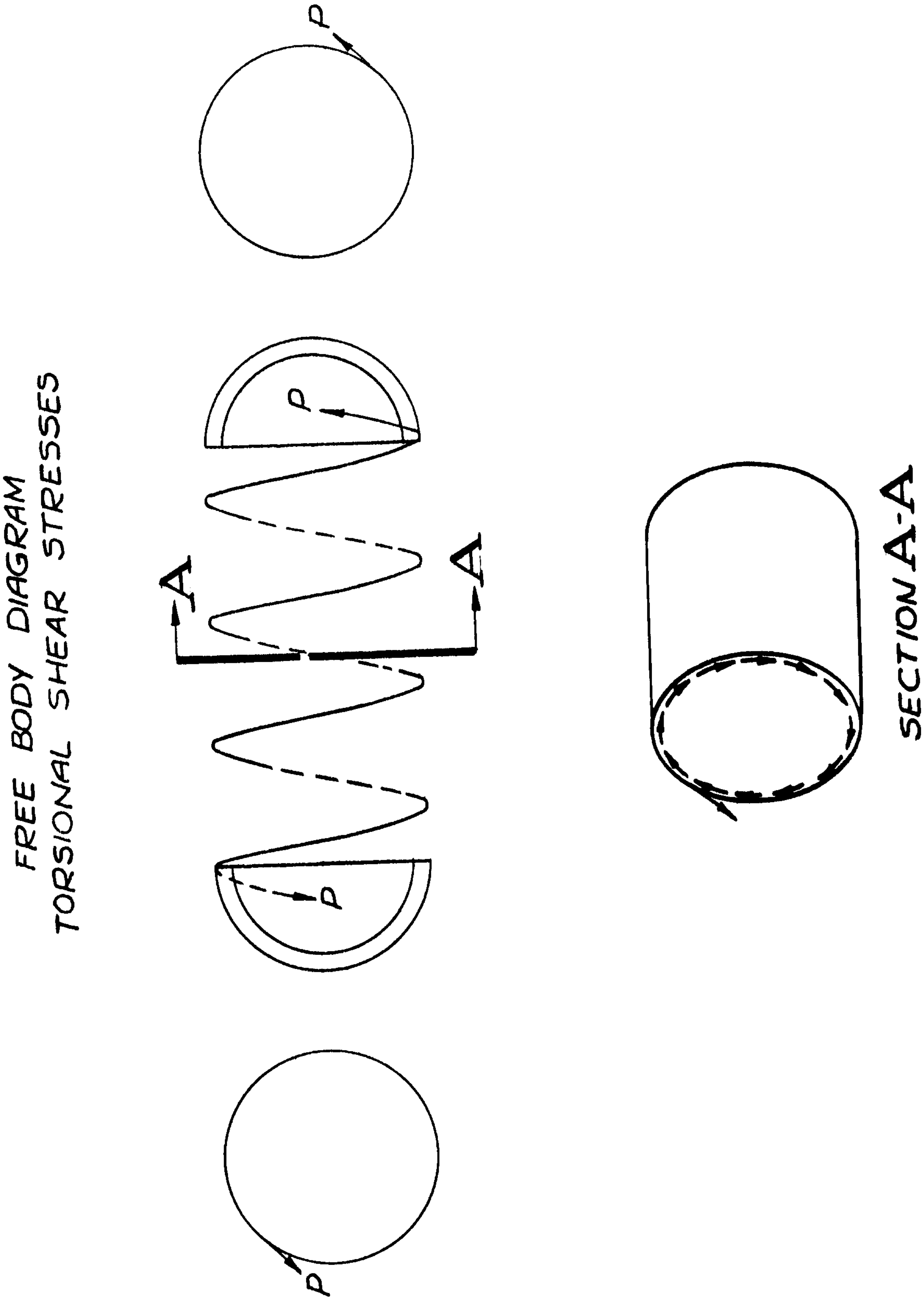
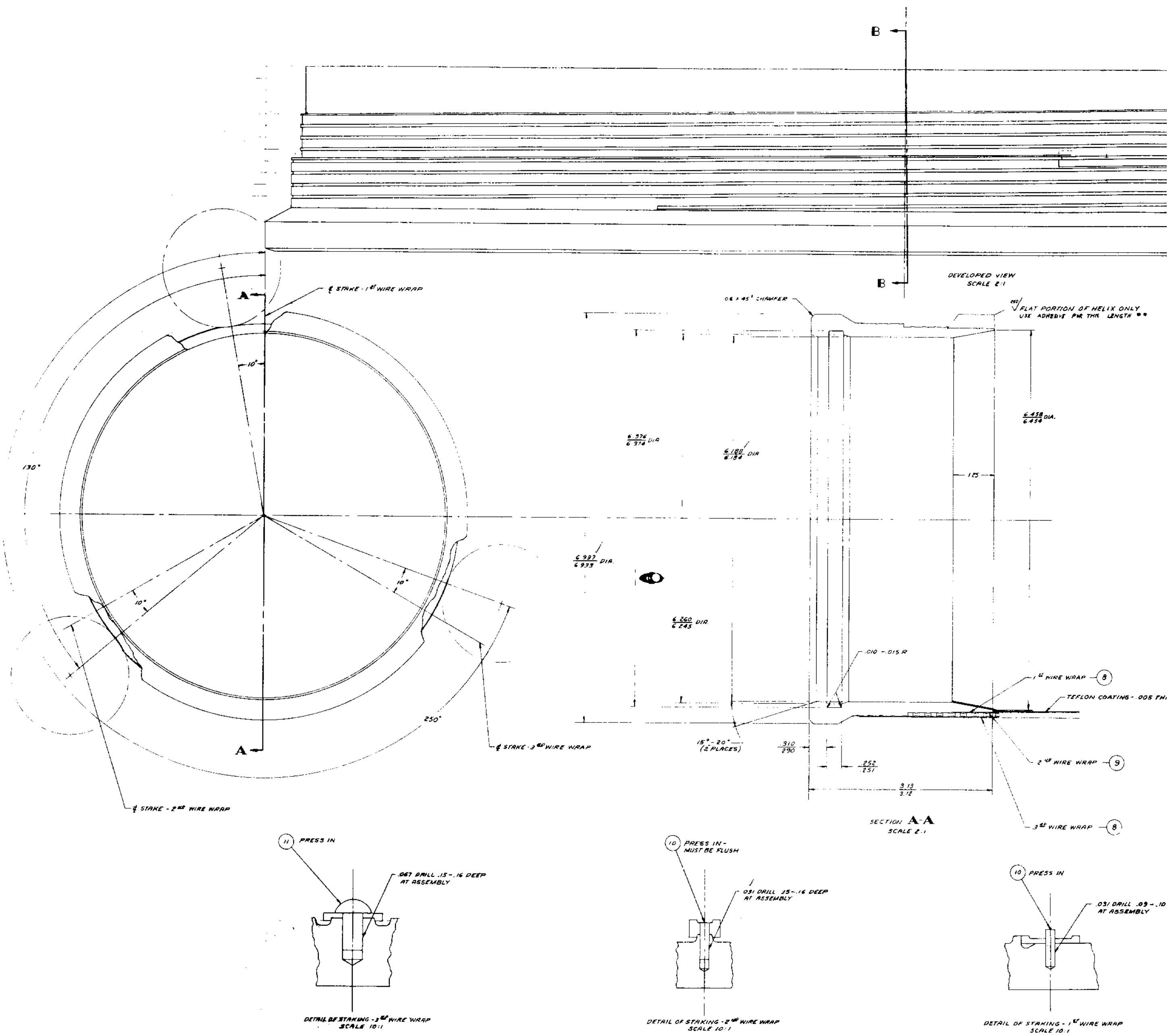
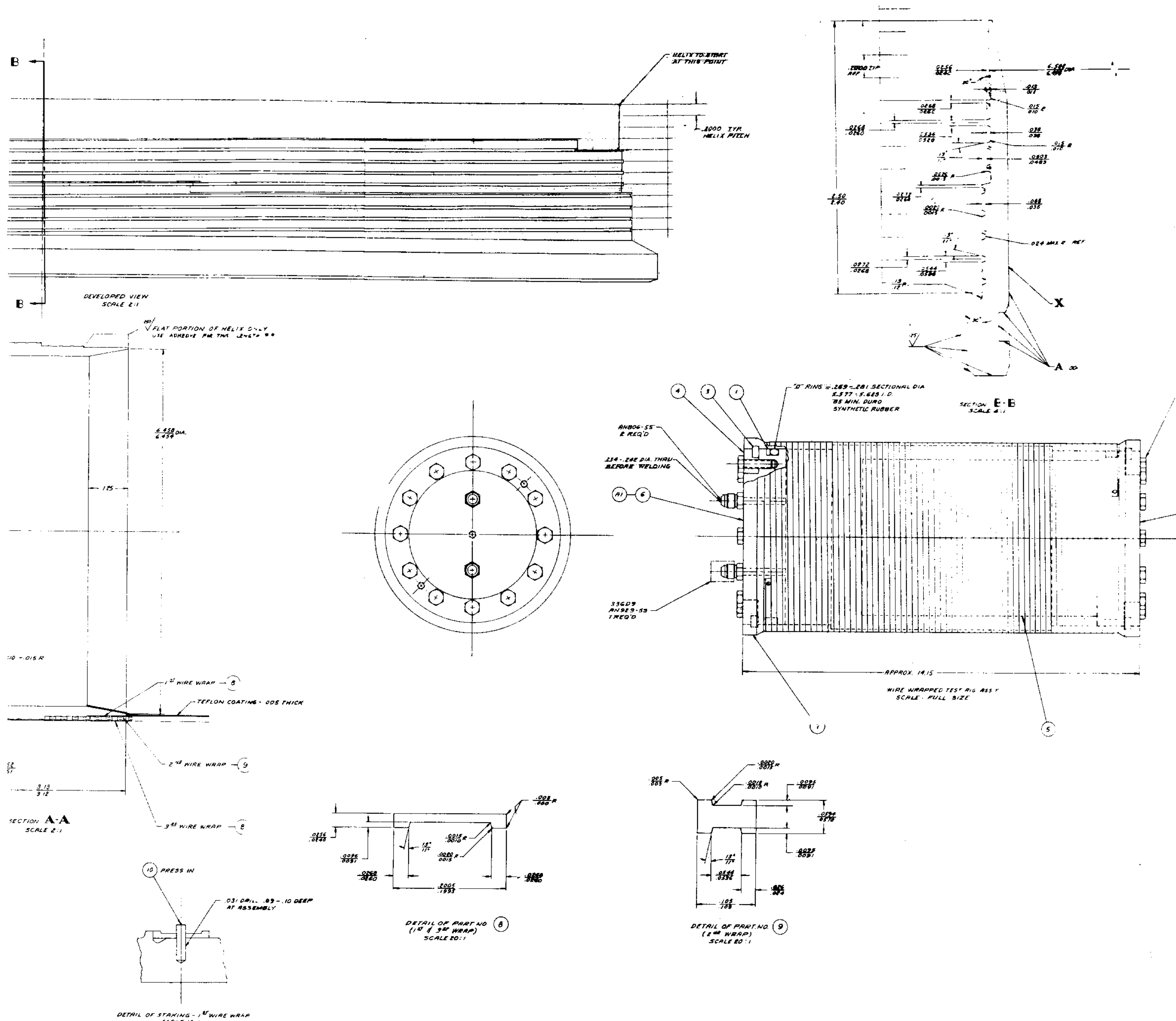
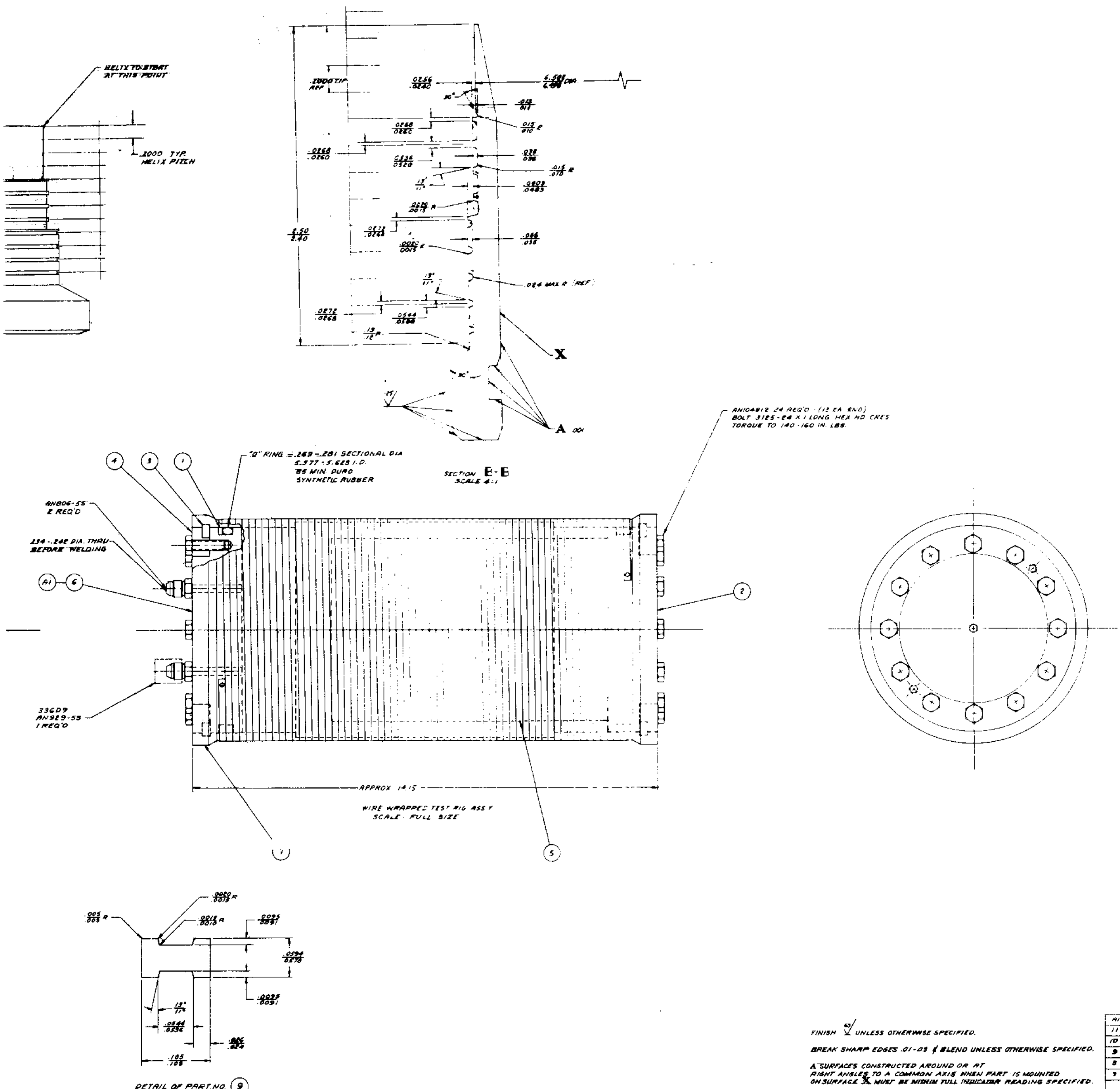

FREE BODY DIAGRAM
TORSIONAL SHEAR STRESSES
A
A
P
P
P
P
SECTION A-A

Figure 10


B
B
A
A
DEVELOPED VIEW
SCALE 2:1
℄ STAKE - 1st WIRE WRAP
.06 x 45° CHAMFER
FLAT PORTION OF HELIX ONLY
USE ADHESIVE FOR THR LENGTH
6.438/6.434 DIA.
6.976/6.974 DIA
6.188/6.184 DIA
1.25
130°
10°
10°
10°
6.937/6.933 DIA.
6.260/6.245 DIA
.010 - .015 R
1st WIRE WRAP (8)
TEFLON COATING - .005 TH
250°
℄ STAKE - 3rd WIRE WRAP
15° - 20° (2 PLACES)
.310/.290
.252/.251
3.13/3.12
2nd WIRE WRAP (9)
SECTION A-A
SCALE 2:1
3rd WIRE WRAP (8)
℄ STAKE - 2nd WIRE WRAP
(11) PRESS IN
.067 DRILL .15-.16 DEEP
AT ASSEMBLY
(10) PRESS IN -
MUST BE FLUSH
.031 DRILL .15-.16 DEEP
AT ASSEMBLY
(10) PRESS IN
.031 DRILL .09-.10
AT ASSEMBLY
DETAIL OF STAKING - 3rd WIRE WRAP
SCALE 10:1
DETAIL OF STAKING - 2nd WIRE WRAP
SCALE 10:1
DETAIL OF STAKING - 1st WIRE WRAP
SCALE 10:1



DEVELOPED VIEW
SCALE 2:1
HELIX TO START AT THIS POINT
SECTION A-A
SCALE 2:1
1ST WIRE WRAP
2ND WIRE WRAP
3RD WIRE WRAP
TEFLON COATING - .005 THICK
"O" RING = .269-.281 SECTIONAL DIA
85 MIN. DURO
SYNTHETIC RUBBER
SECTION B-B
AN806-5S
2 REQ'D
BEFORE WELDING
APPROX. 14.15
WIRE WRAPPED TEST RIG ASS'Y
SCALE: FULL SIZE
PRESS IN
AT ASSEMBLY
DETAIL OF STAKING - 1ST WIRE WRAP
SCALE 10:1
DETAIL OF PART NO 8
(1ST & 3RD WRAP)
SCALE 20:1
DETAIL OF PART NO 9
(2ND WRAP)
SCALE 20:1



FINISH $\overset{63}{\checkmark}$ UNLESS OTHERWISE SPECIFIED.

BREAK SHARP EDGES .01-.03 & BLEND UNLESS OTHERWISE SPECIFIED.

A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED.

* PURCHASE FROM:
GROOV-PIN CORP.
1125 HENDRICKS CAUSEWAY
RIDGEFIELD, N.J.

** MARBLETTE INC.
RESIN NO. 532
HARDNER NO. 37
$S_{s(\text{shear})}$ = 4500 PSI

LS25439

ITEM NO.	PART NO. (ADD)	ASS'Y (ADD)	PART NO. (REFERENCE)	PART NO. (CANCEL)	QUAN	DESCRIPTION	MATERIAL	MAT'L	OTHER SPECS	FORG CAST W.E.
A1	LS23896A1				1	PLUG & FITTING ASS'Y				
11					2	ROUND HD DRIVE STUD NO. 6		SAE 6150	1/4 LONG	
10					4	GROOV PIN TYPE 3 - 1/32 DIA *		SAE 6150	1/4 LONG	
9					AS REQ'D	WIRE - I BEAM		8120 VCA		
8					AS REQ'D	WIRE - CHANNEL		8120 VCA		
7					2	ADAPTER - WIRE R_c 46-50		[illegible]	[illegible]	
	A929-5S				1	CAP ASS'Y - PRESS SEAL		CORR RESIST STEEL	[illegible]	
	AN806-5S	A1			2	PLUG - FLARED TUBE		CORR RESIST STEEL	[illegible]	
6	LS23890-7	A1			1	PLUG - INLET		SAE 4340 SAE 8740	RC 19-26	
5	LS23890-6				1	CYLINDER		OPTIONAL		
	AN104812				24	BOLT - HEX. HD. .3125 24 X 1" LG		CRES		
					2	"O" RING - 5.600 I.D. .275 SECT. DIA		SYNTHETIC RUBBER	85 [illegible]	
4	LS23890-5				2	PLATE - RESTRAINING		SAE 4340 SAE 8740	RC 19-26	
3	LS23890-4				6	RING - SEGMENT		SAE 4340 SAE 8740 [illegible]	RC 47-51	
2	LS23890-3				1	PLUG - PLAIN		SAE 4340 SAE 8740	RC 19-26	
1	LS23890-2				2	RING - BACK-UP		LEATHER		

PARTS LIST

SCALE AS INDICATED

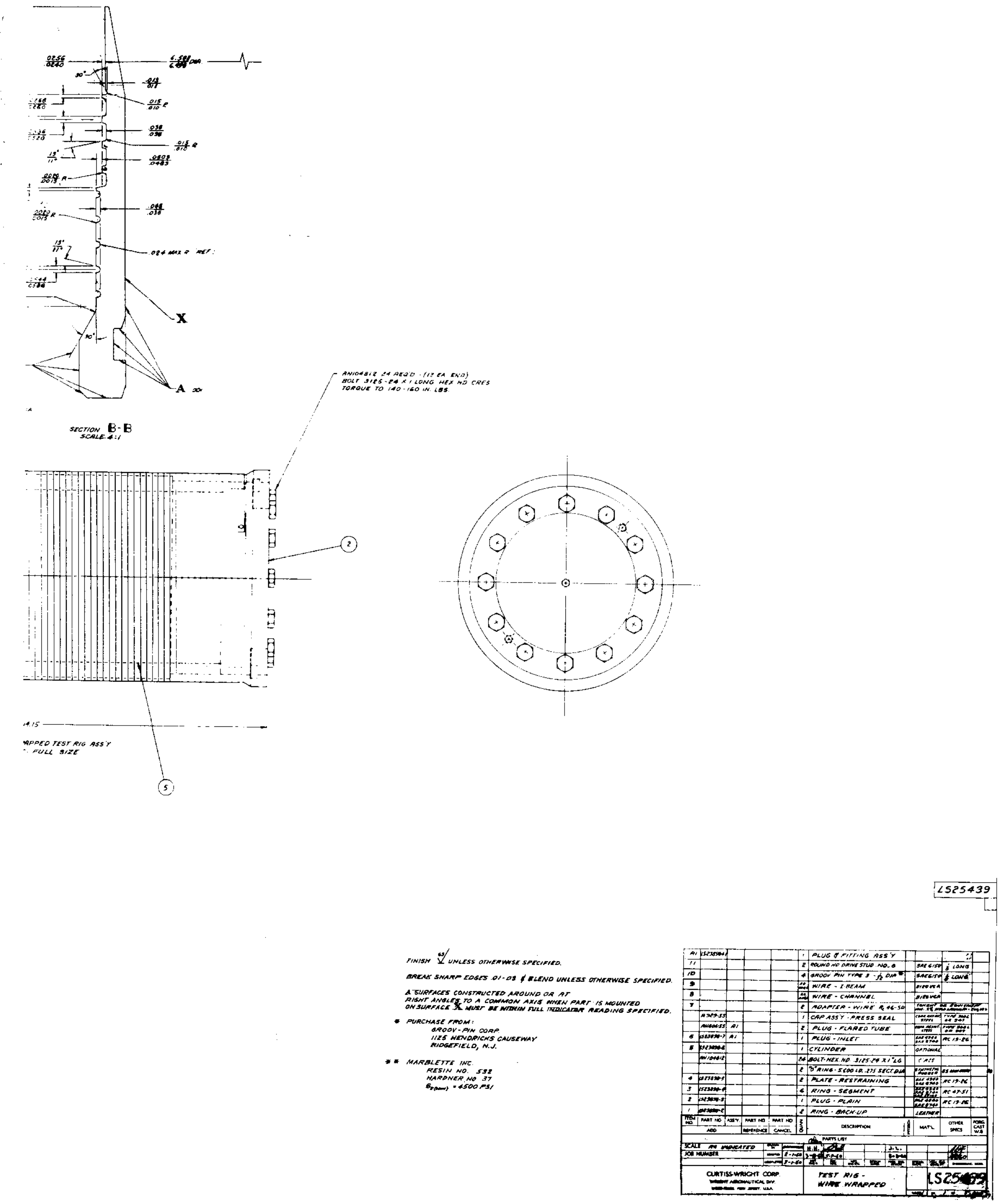
JOB NUMBER

CURTISS-WRIGHT CORP.
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY U.S.A.

TEST RIG - WIRE WRAPPED

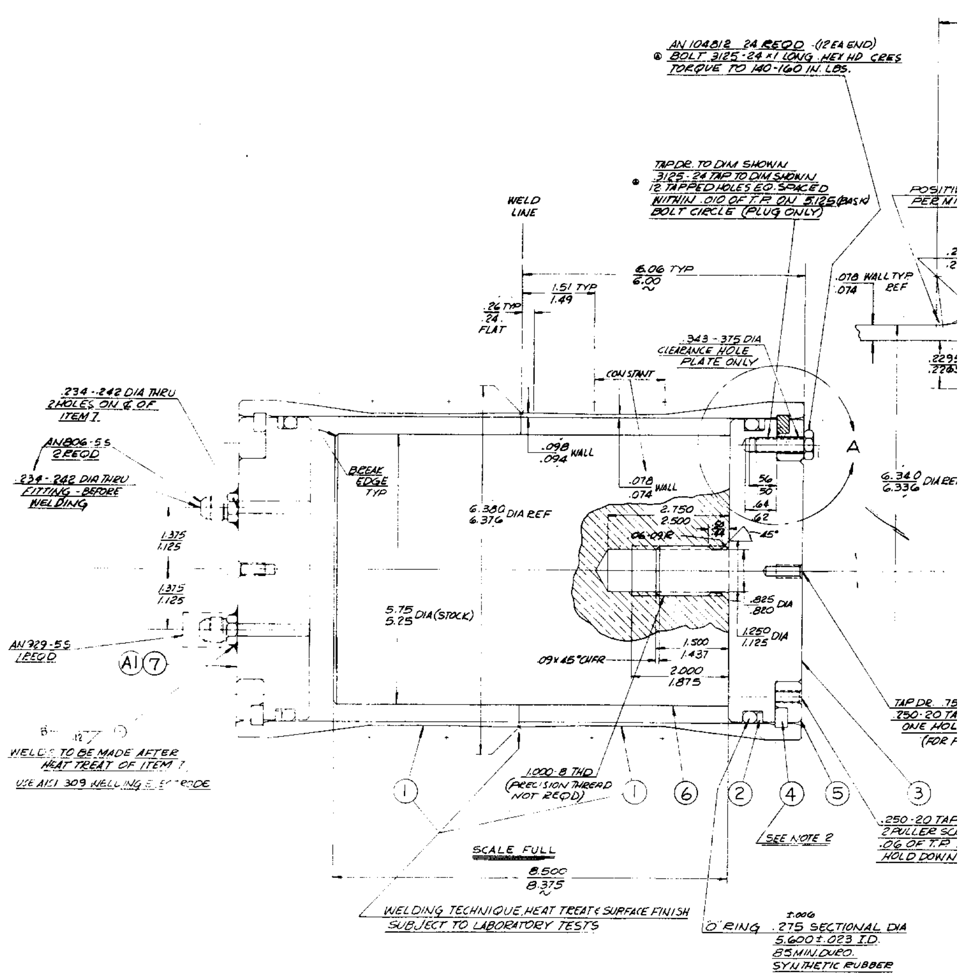
LS25439

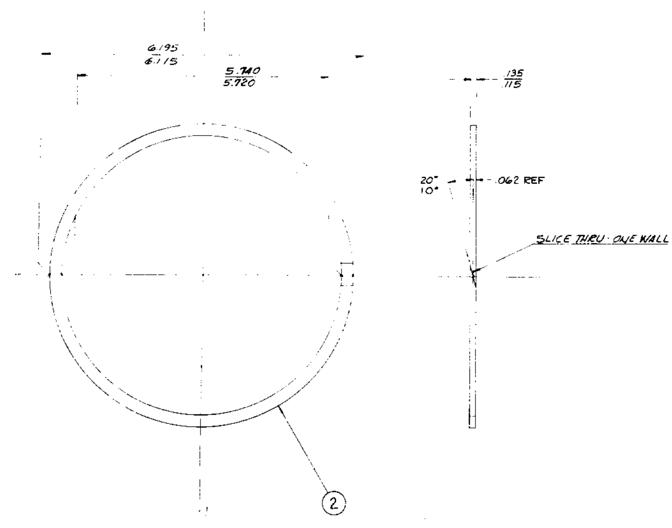
Figure 11

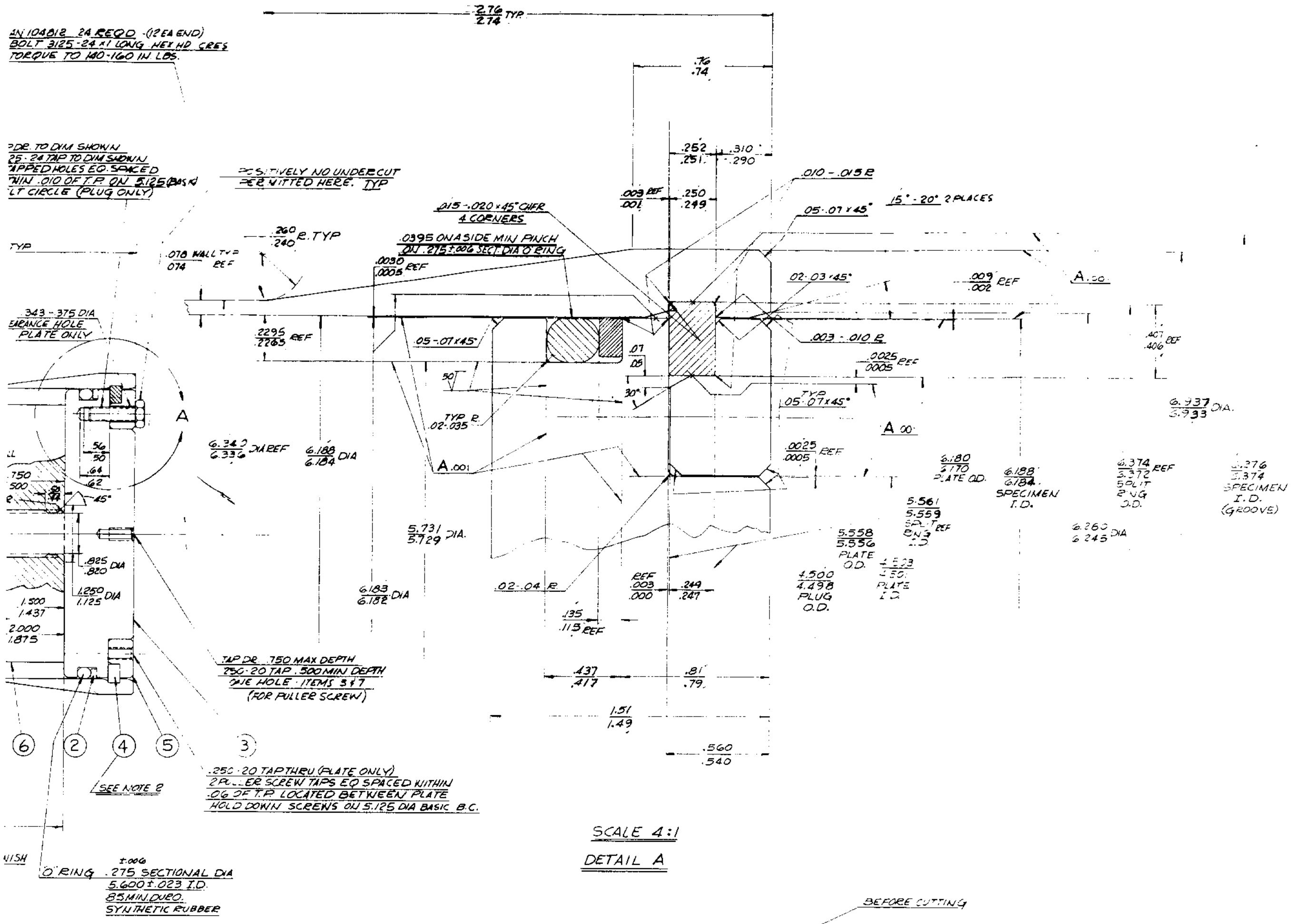


SECTION B-B
SCALE 4:1
X
A
AN104812 24 REQ'D (12 EA END)
BOLT .3125-24 X 1 LONG HEX HD CRES
TORQUE TO 140-160 IN. LBS.
FULL SIZE
LS25439
FINISH 63 UNLESS OTHERWISE SPECIFIED.
BREAK SHARP EDGES .01-.03 & BLEND UNLESS OTHERWISE SPECIFIED.
A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED.
* PURCHASE FROM:
GROOV-PIN CORP.
1125 HENDRICKS CAUSEWAY
RIDGEFIELD, N.J.
** MARBLETTE INC.
RESIN NO. 532
HARDNER NO 37
$S_{T(min)}$ = 4500 PSI
PLUG & FITTING ASS'Y
ROUND HD DRIVE STUD NO. 6
GROOV PIN TYPE 3 - 1/8 DIA
WIRE - I-BEAM
WIRE - CHANNEL
ADAPTER - WIRE
CAP ASS'Y - PRESS SEAL
PLUG - FLARED TUBE
PLUG - INLET
CYLINDER
BOLT-HEX HD .3125-24 X 1" LG
"O" RING
PLATE - RESTRAINING
RING - SEGMENT
PLUG - PLAIN
RING - BACK-UP
ITEM NO.
PART NO.
ASS'Y.
DESCRIPTION
MAT'L.
OTHER SPECS
PARTS LIST
SCALE AS INDICATED
JOB NUMBER
CURTISS-WRIGHT CORP.
WRIGHT AERONAUTICAL DIV.
TEST RIG - WIRE WRAPPED

Figure 11

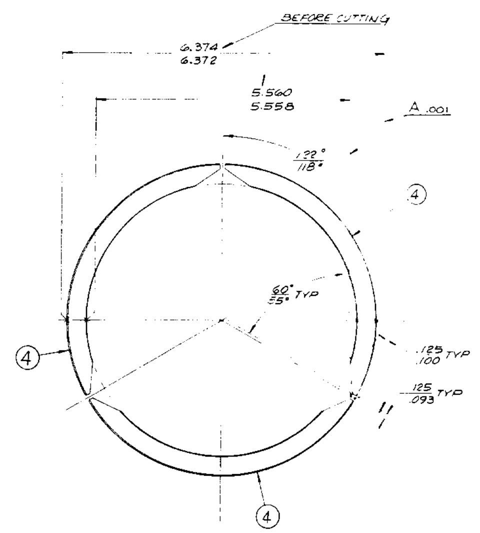

AN 104812 24 REQD (12 EA END)
BOLT 3125-24 x1 LONG HEX HD CRES
TORQUE TO 140-160 IN. LBS.
TAP DR. TO DIM SHOWN
.3125-24 TAP TO DIM SHOWN
12 TAPPED HOLES EQ. SPACED
WITHIN .010 OF T.P. ON 5.125 (BASIC)
BOLT CIRCLE (PLUG ONLY)
WELD LINE
6.06 TYP
6.00
1.51 TYP
1.49
.26 TYP
.24
FLAT
.078 WALL TYP
.074 REF
.343-.375 DIA
CLEARANCE HOLE
PLATE ONLY
CONSTANT
.234-.242 DIA THRU
2 HOLES ON ℄ OF ITEM 7.
AN806-5S
2 REQD
.234-.242 DIA THRU
FITTING - BEFORE WELDING
BREAK EDGE TYP
.098 WALL
.094
.078 WALL
.074
A
6.380 DIA REF
6.376
2.750
2.500
.06-.09R
45°
6.340 DIA REF
6.336
1.375
1.125
5.75 DIA (STOCK)
5.25
.825 DIA
.820
1.250 DIA
1.125
AN929-5S
1 REQD
A1 7
.09 x 45° CHFR
1.500
1.437
2.000
1.875
WELDS TO BE MADE AFTER
HEAT TREAT OF ITEM 7
1.000-8 THD
(PRECISION THREAD NOT REQD)
1 1 6 2 4 5 3
SEE NOTE 2
SCALE FULL
8.500
8.375
WELDING TECHNIQUE, HEAT TREAT & SURFACE FINISH
SUBJECT TO LABORATORY TESTS
O RING .275 SECTIONAL DIA ±.006
5.600 ±.023 I.D.
85 MIN. DURO.
SYNTHETIC RUBBER
.250-20 TAP
2 PULLER SC
.06 OF T.P.
HOLD DOWN


6.195
6.175
5.740
5.720
.135
.115
20°
10°
.062 REF
SLICE THRU ONE WALL
2



SCALE 4:1

DETAIL A



A1					1	PLUG & FITTING ASSEMBLY			WELD AFTER HEAT TREAT	
	A929-5S				1	CAP ASSEMBLY, PRESS SEAL		CORR RESIST STL	TYPE 304L OR 347	
	AN806-5S	A1			2	PLUG - FLARED TUBE		CORR RESIST STL	TYPE 304L OR 347	
7		A1			1	PLUG - INLET		SAE 4340 SAE 8740	RC 19-26	
6					1	CYLINDER		OPTIONAL		
Ⓐ	AN104812				24	BOLT HEX. HD. .3125-24 x 1 LG. CRES				
					2	O'RING - 5.600 I.D., .275 SECTIONAL DIA		SYNTHETIC RUBBER	85 MIN DURO	
5					2	PLATE - RESTRAINING		SAE 4340 SAE 8740	RC 19-26	
4					6	RING - SEGMENT		[illegible]	RC 47-51	
3					1	PLUG - PLAIN		SAE 4340 SAE 8740	RC 19-26	
2					2	RING - BACK-UP - LEATHER				
1					2	SPECIMEN				
ITEM	PART NO. REQD	AND	PART NO. REFERENCE	PART NO. CANCEL	QUAN	DESCRIPTION	INTERCH	MATL	OTHER SPECS	FORG CAST WR

FINISH 125 UNLESS OTHE

BREAK SHARP EDGES INDICATED.

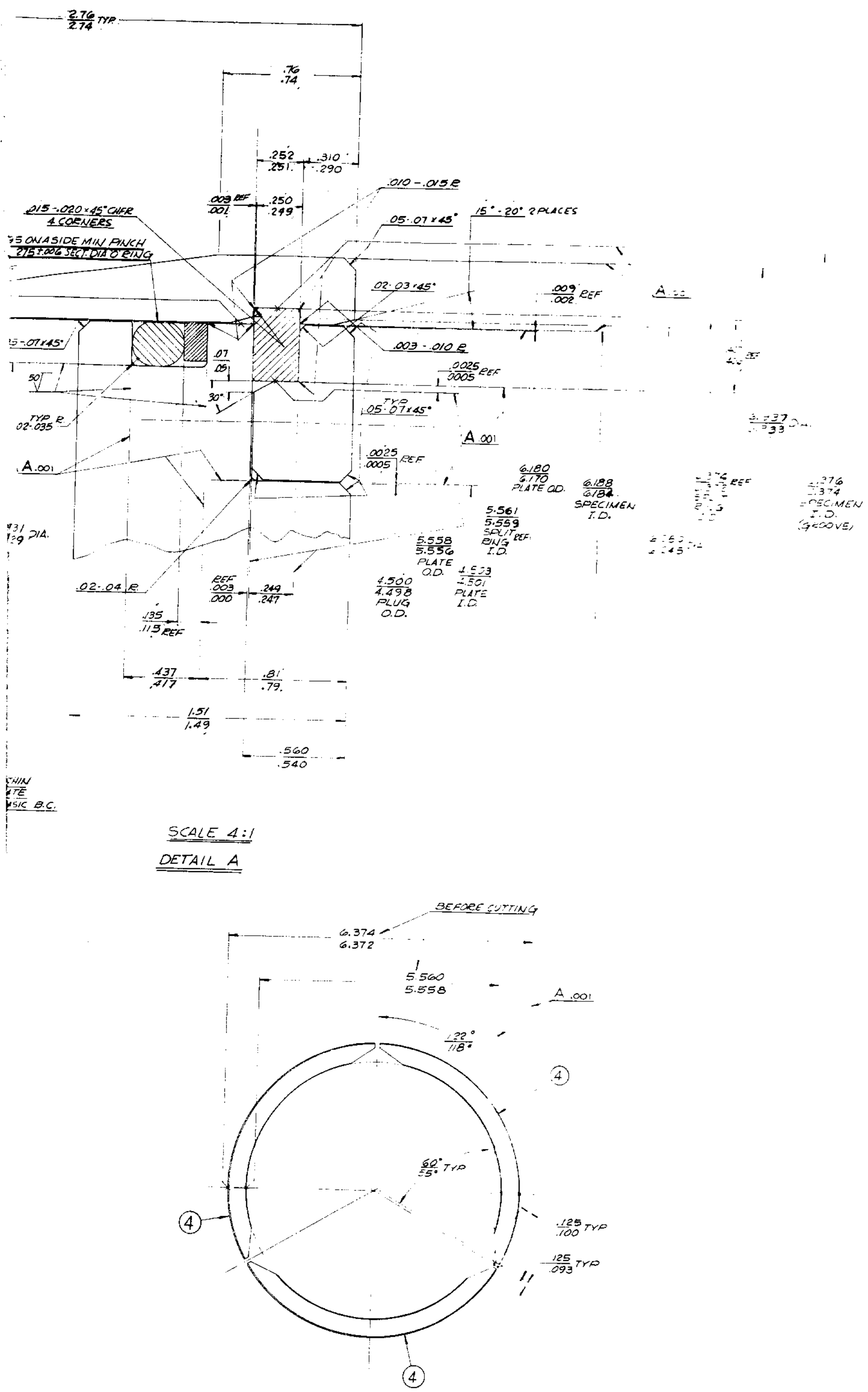
A SURFACES CONST RIGHT ANGLES TO A WITHIN FULL INDICAT

CURTISS-WRIGHT CORP. WRIGHT AERONAUTICAL DIV. WOOD-RIDGE, NEW JERSEY, U.S.A.

GIRTH WELD -RE DESIG

5-20-

5-22-



LS23898
A

ITEM	PART NO.	ASSY	PART NO. ALTERED	PART NO. CANCEL	QUAN	DESCRIPTION	INTERC.	MATL	OTHER SPECS	FORG CAST NR
A1						PLUG & FITTING ASSEMBLY			WELD AFTER HEAT TREAT	
	A929-5S					CAP ASSEMBLY PRESS SEAL		STL	TYPE 304L OR 347	
	AN806-5S	A1			2	PLUG - FLARED TUBE		CORR. RESIST STL	TYPE 304L OR 347	
7		A1				PLUG - INLET		SAE 4340 SAE 8740	RC 19-26	
6						CYLINDER		OPTIONAL		
Ⓐ	AN104812				24	BOLT HEX HD. 3125-24x1LG. CRES				
					2	O RING 5.600 I.D., .275 SECTIONAL DIA		SYNTHETIC RUBBER	85 MIN DURO	
5					2	PLATE - RESTRAINING		SAE 4340 SAE 8740	RC 19-26	
4					6	RING - SEGMENT			RC 47-51	
3					1	PLUG - PLAIN		SAE 4340 SAE 8740	RC 19-26	
2					2	RING - BACK-UP - LEATHER				
1					2	SPECIMEN				

FINISH 125 √ UNLESS OTHERWISE SPECIFIED

BREAK SHARP EDGES .01 - .03 UNLESS OTHERWISE INDICATED.

A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS MUST BE WITHIN FULL INDICATOR READING SPECIFIED.

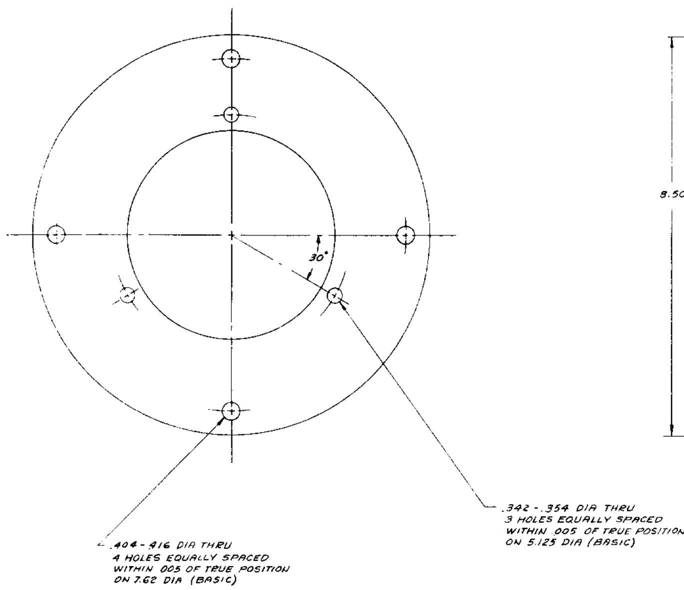
5-20-59 5-22-59 5-28-59

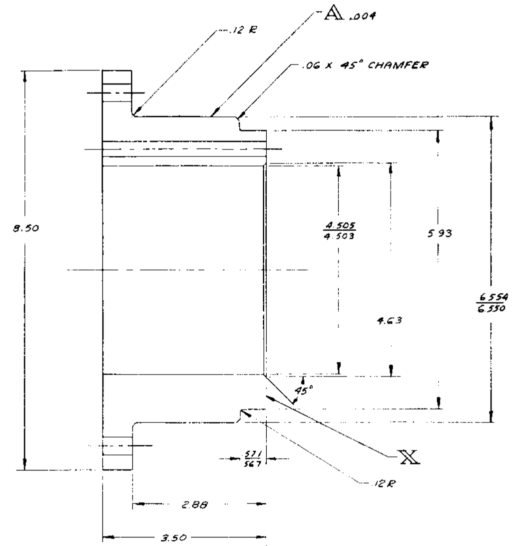
CURTISS-WRIGHT CORP. WRIGHT AERONAUTICAL DIV. WOOD-RIDGE, NEW JERSEY, U.S.A.

GIRTH WELD RIG -RE DESIGN-

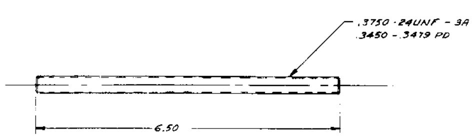
LS23898

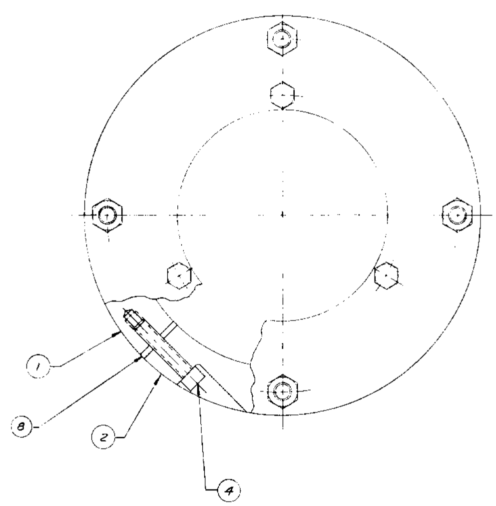
Figure 12

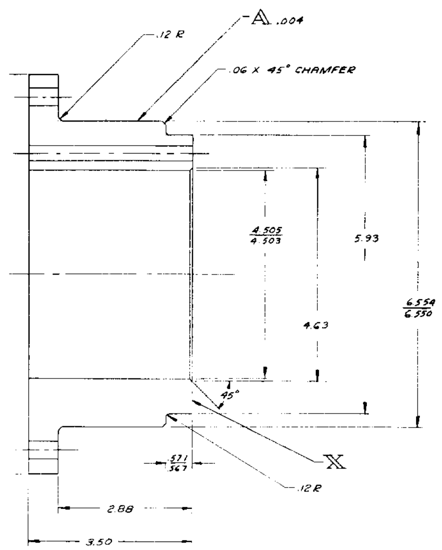

30°
.404 - .416 DIA THRU
4 HOLES EQUALLY SPACED
WITHIN .005 OF TRUE POSITION
ON 7.62 DIA (BASIC)
.342 - .354 DIA THRU
3 HOLES EQUALLY SPACED
WITHIN .005 OF TRUE POSITION
ON 5.125 DIA (BASIC)

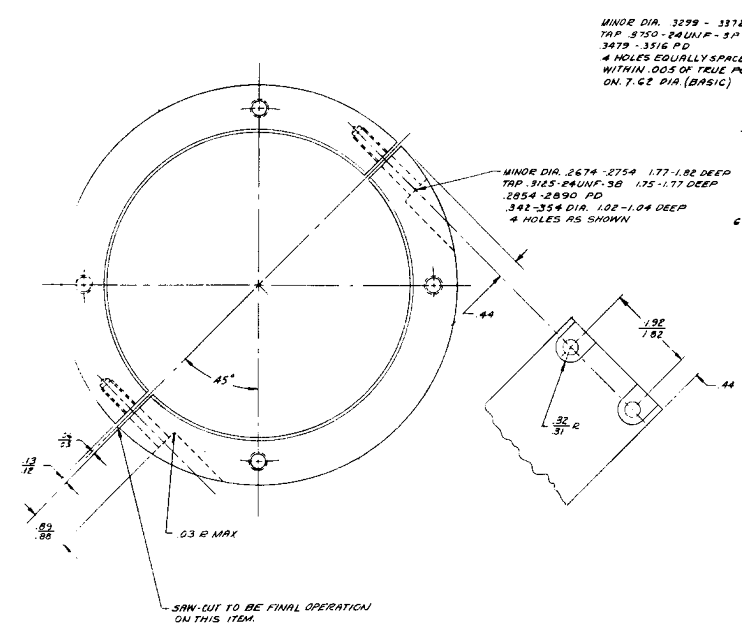

.12 R
A .004
.06 X 45° CHAMFER
8.50
4.505
4.503
5.93
6.554
6.550
4.63
45°
X
.12 R
.571
.567
2.88
3.50

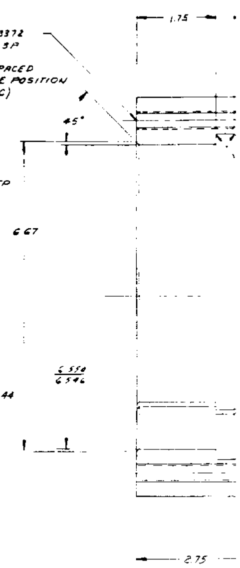

.06
.03
.13
.12
.89
.88

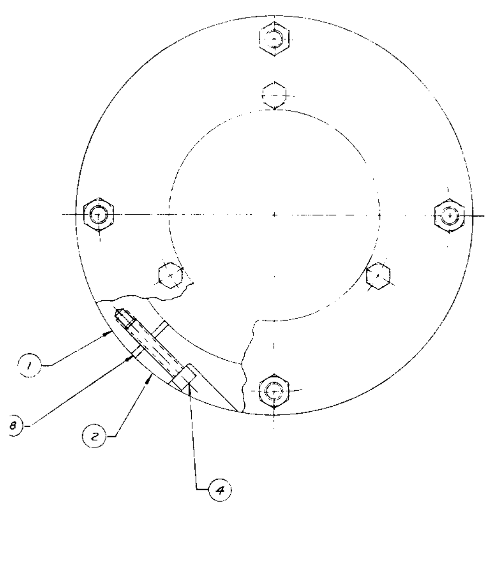

.3750 -24UNF - 3A
.3450 - .3479 PD
6.50

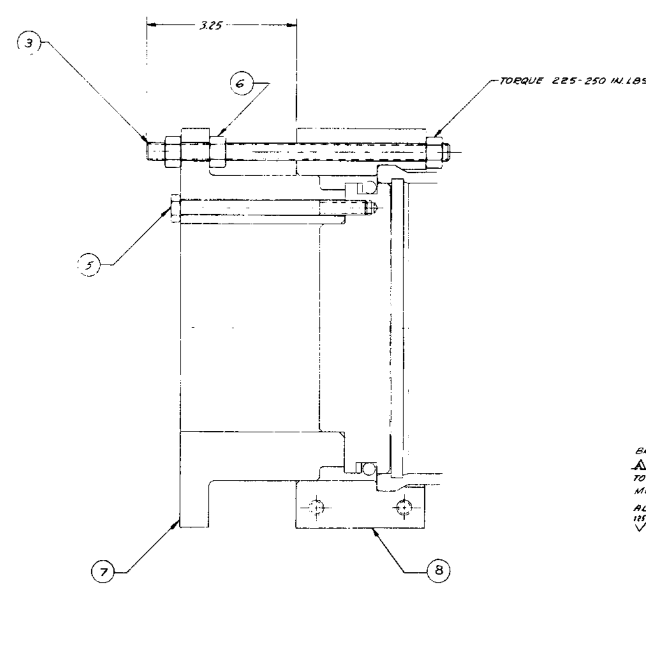

1
8
2
4











BREAK SHARP EDGES .01 - .02 & BLEN
A SURFACES CONSTRUCTED AROUND
TO A COMMON AXIS WHEN PART IS MOU
MUST BE WITHIN FULL INDICATED REA
ALL NOTES APPLY UNLESS OTHERWI
125/ ALL OVER

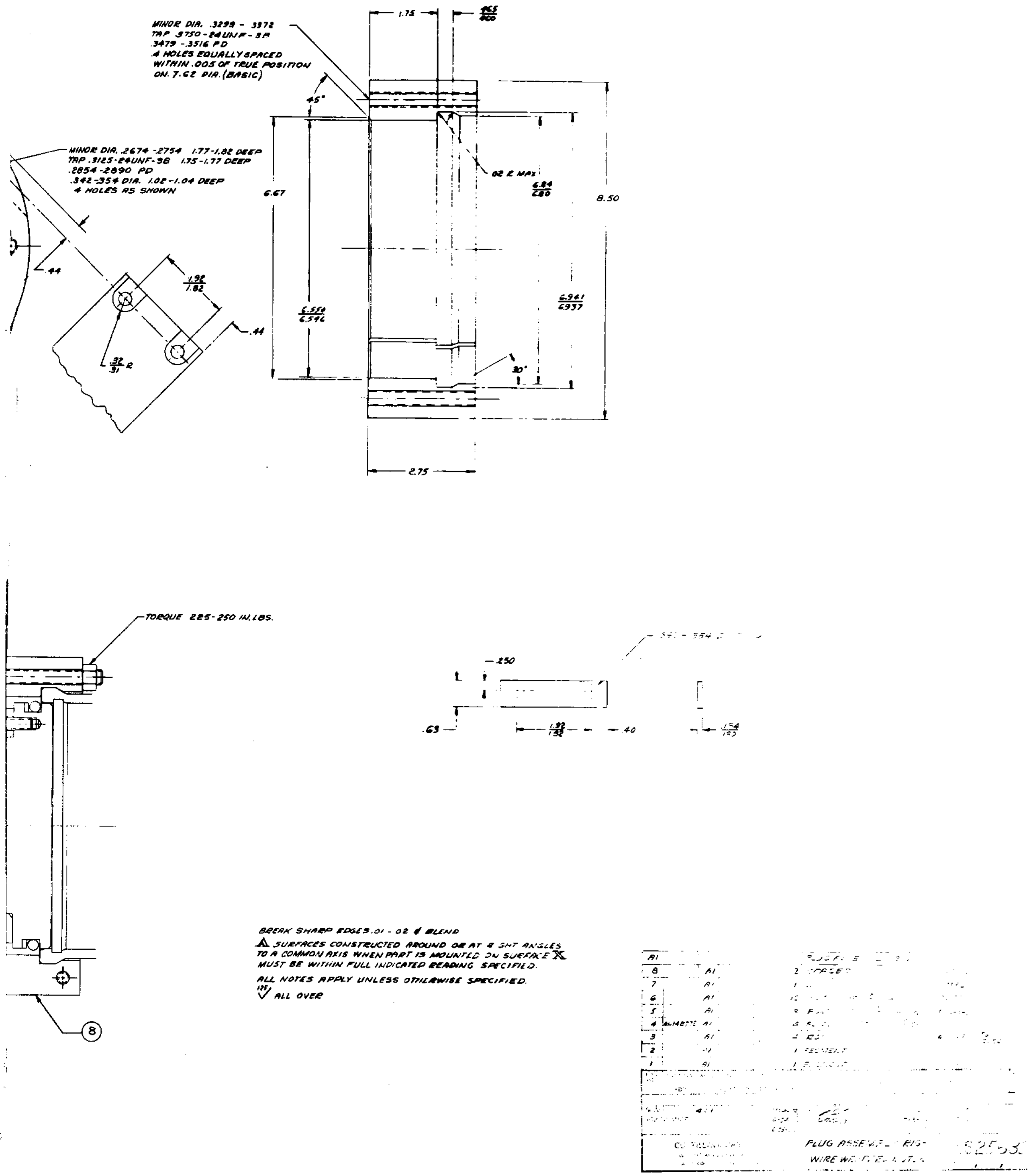

MINOR DIA. .3299 - .3372
TAP .3750-24UNF-3B
.3479 - .3516 PD
4 HOLES EQUALLY SPACED
WITHIN .005 OF TRUE POSITION
ON 7.62 DIA. (BASIC)
MINOR DIA. .2674 -.2754 1.77-1.82 DEEP
TAP .3125-24UNF-3B 1.75-1.77 DEEP
.2854-.2890 PD
.342-.354 DIA. 1.02-1.04 DEEP
4 HOLES AS SHOWN
1.75
2.75
45°
30°
6.67
8.50
.44
TORQUE 225-250 IN. LBS.
8
BREAK SHARP EDGES .01 - .02 & BLEND
ALL NOTES APPLY UNLESS OTHERWISE SPECIFIED.
ALL OVER

Figure 13

FREEBODY DIAGRAM

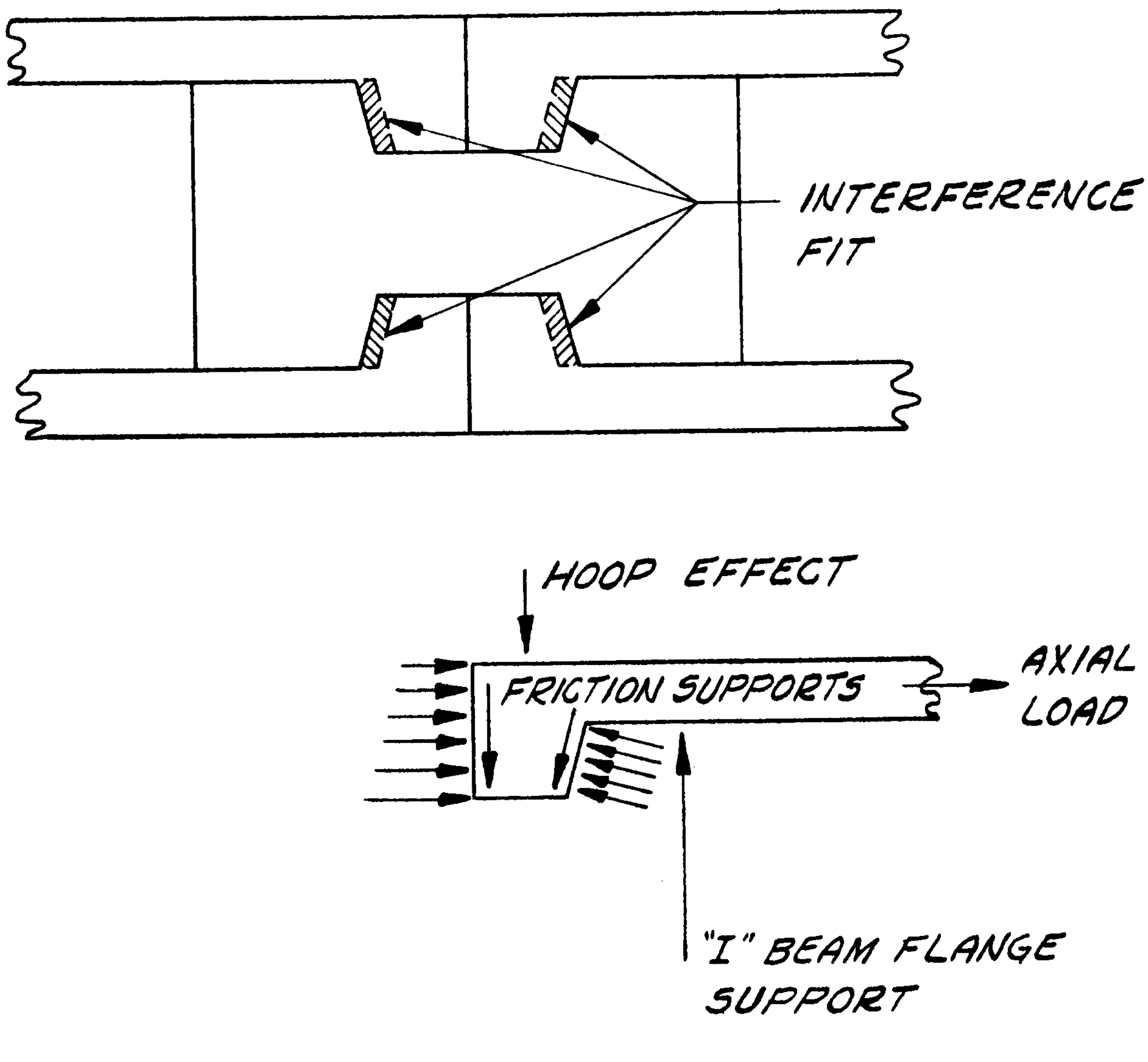
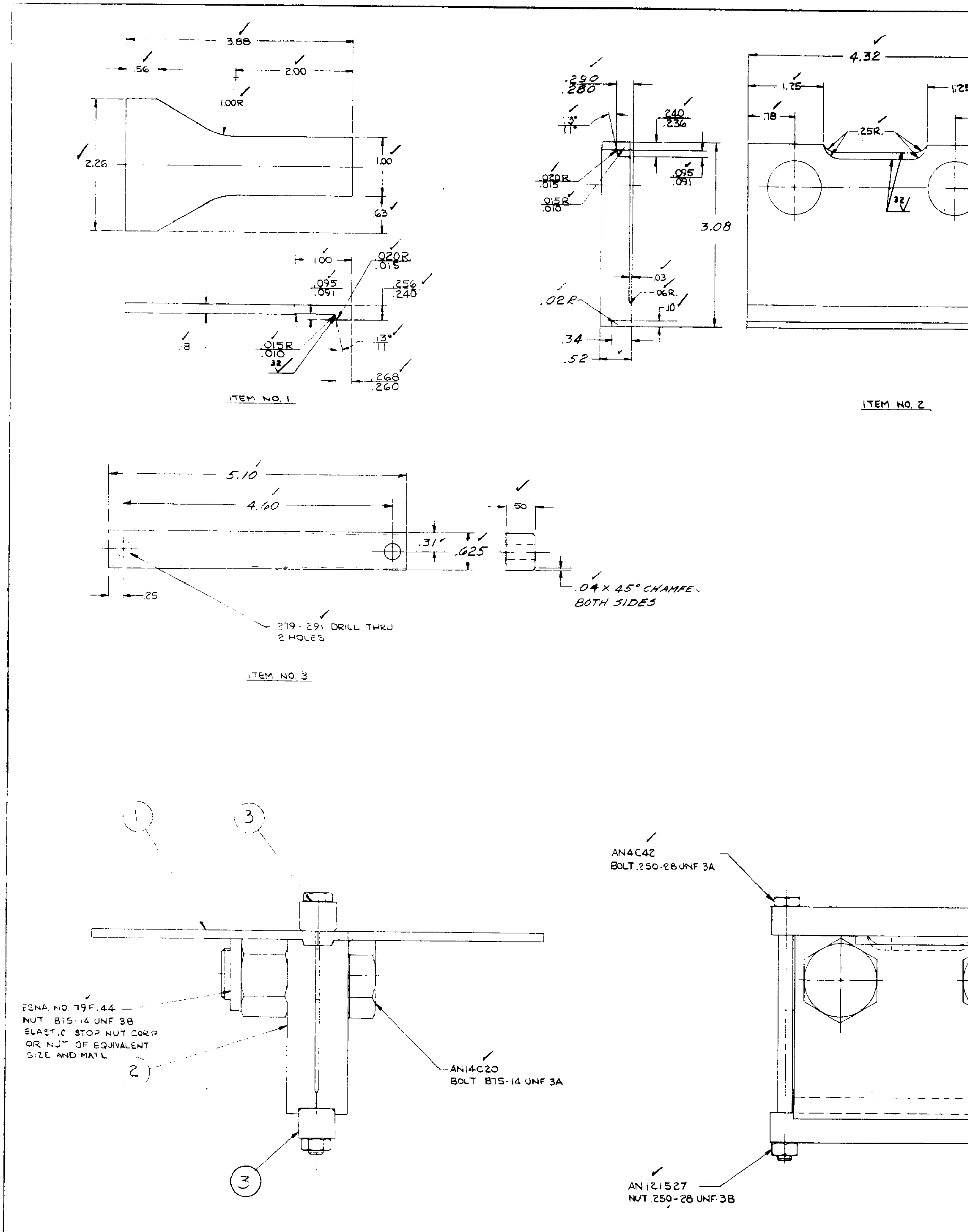
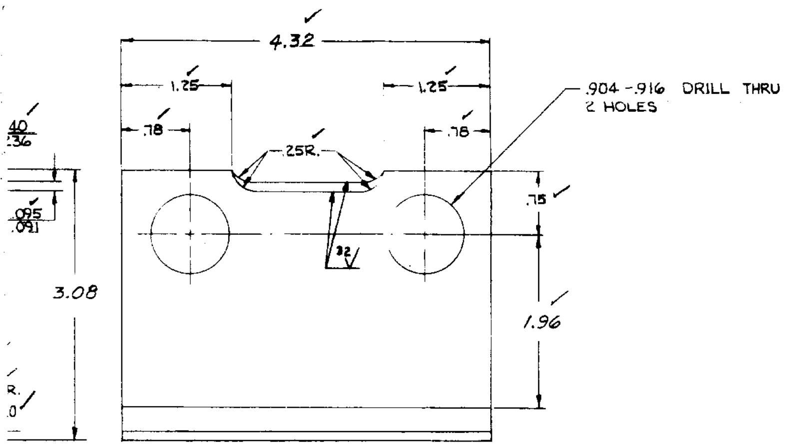


Figure 14


3.88
.56
2.00
1.00R.
2.26
1.00
.63
1.00
.020R
.015
.095
.091
.256
.240
.8
.015R
.010
.13°
.11
.268
.260
ITEM NO. 1
.290
.280
.13°
.11
.240
.236
.020R
.015
.015R
.010
.095
.091
3.08
.03
.06R.
.02R
.10
.34
.52
4.32
1.75
1.25
.78
.25R.
32
ITEM NO. 2
5.10
4.60
.31
.625
.50
.25
.279 .291 DRILL THRU
2 HOLES
.04 x 45° CHAMFER
BOTH SIDES
ITEM NO. 3
1
3
ESNA NO. 79F144 —
NUT .875-14 UNF 3B
ELASTIC STOP NUT CORP
OR NUT OF EQUIVALENT
SIZE AND MAT'L
2
AN14C20
BOLT .875-14 UNF 3A
3
AN4C42
BOLT .250-28 UNF 3A
AN121527
NUT .250-28 UNF 3B



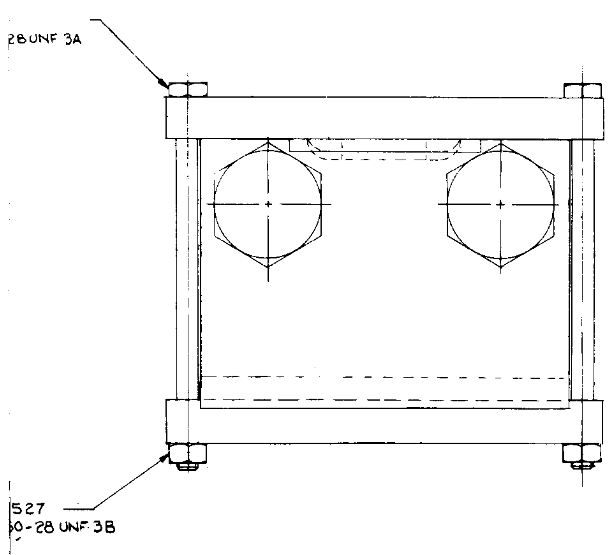
ITEM NO. 2

FINISH 125

BREAK SHARP EDGES
.005-.015 APPROX R

FINISHED DIM. ±.010
ALL ANGLES ± 2°

ALL NOTES APPLY
UNLESS OTHERWISE SPECIFIED



	AN14C20				2	BOLT-.875-14UNF 3A 2 3/16 LENGTH
	ESNA NO. 79E144 OR EQUIVALENT				2	NUT-.875-14UNF 3B (SEE NOTE)
	AN4C42				2	BLOT-.250-28 UNF-3A 4 9/32 LENGTH
	AN121527				2	NUT-.250-28UNF3B
3					2	PLATE - SPECIMEN CLAMP
2					2	CLAMP - "I" BEAM
1					2	SPECIMEN - CHANNEL 10/1 WIRE SIZE
ITEM	[illegible]	ASSY	[illegible]	PART NO.	[illegible]	DESCRIPTION

SCALE FULL
JOB NUMBER 650032

Zawonski H.H J.L.
10-25-60 11-1-60 11-1-6[illegible]
10-27-60

CURTISS [illegible]

INTER-LOCKING TITANIUM
WIRE CASE -
CHANNEL & "I"-BEAM JOINT RIG

L THRU

REVISIONS			
CHG. LTR.	DESCRIPTION	DATE	ENGRS.

FINISH $\sqrt[125]{}$

BREAK SHARP EDGES
.005-.015 APPROX R

FINISHED DIM. ±.010
ALL ANGLES ± 2°

ALL NOTES APPLY
UNLESS OTHERWISE SPECIFIED

LS 25810

ITEM	PART NO. ADD	ASSY	PART NO. REFERENCE	PART NO. CANCEL	QTY	DESCRIPTION	MAT'L	OTHER SPECS	FORG CAST W.R.
	AN14C20				2	BOLT-.875-14UNF 3A 2 3/16 LENGTH	CORROSION RESISTANT STEEL		
	ESNA NO. 79E144 OR EQUIVALENT				2	NUT-.875-14UNF 3B (SEE NOTE)	STAINLESS STEEL		
	AN4C42				2	BLOT-.250-28 UNF-3A 4 9/32 LENGTH	CORROSION RESISTANT STEEL		
	AN121527				2	NUT-.250-28UNF3B	CORROSION RESISTANT STEEL		
3					2	PLATE - SPECIMEN CLAMP	AISI 431	RC 32-36	
2					2	CLAMP-'I' BEAM	TITANIUM B120VCA	180,000 Min. Yield	
1					2	SPECIMEN-CHANNEL 10/1 WIRE SIZE	TITANIUM B120VCA	180,000 Min. Yield	

SCALE FULL	ZAWONSKI 10-25-60	H.H 11-1-60	J.L. 11-1-60	UBF 11/3/60 ENGINEERING MGR.
JOB NUMBER 650032	10-27-60			
CURTISS	INTER-LOCKING TITANIUM WIRE CASE - CHANNEL & 'I' BEAM JOINT RIG		LS 25810	1 OF 1 SHEETS

Figure 15

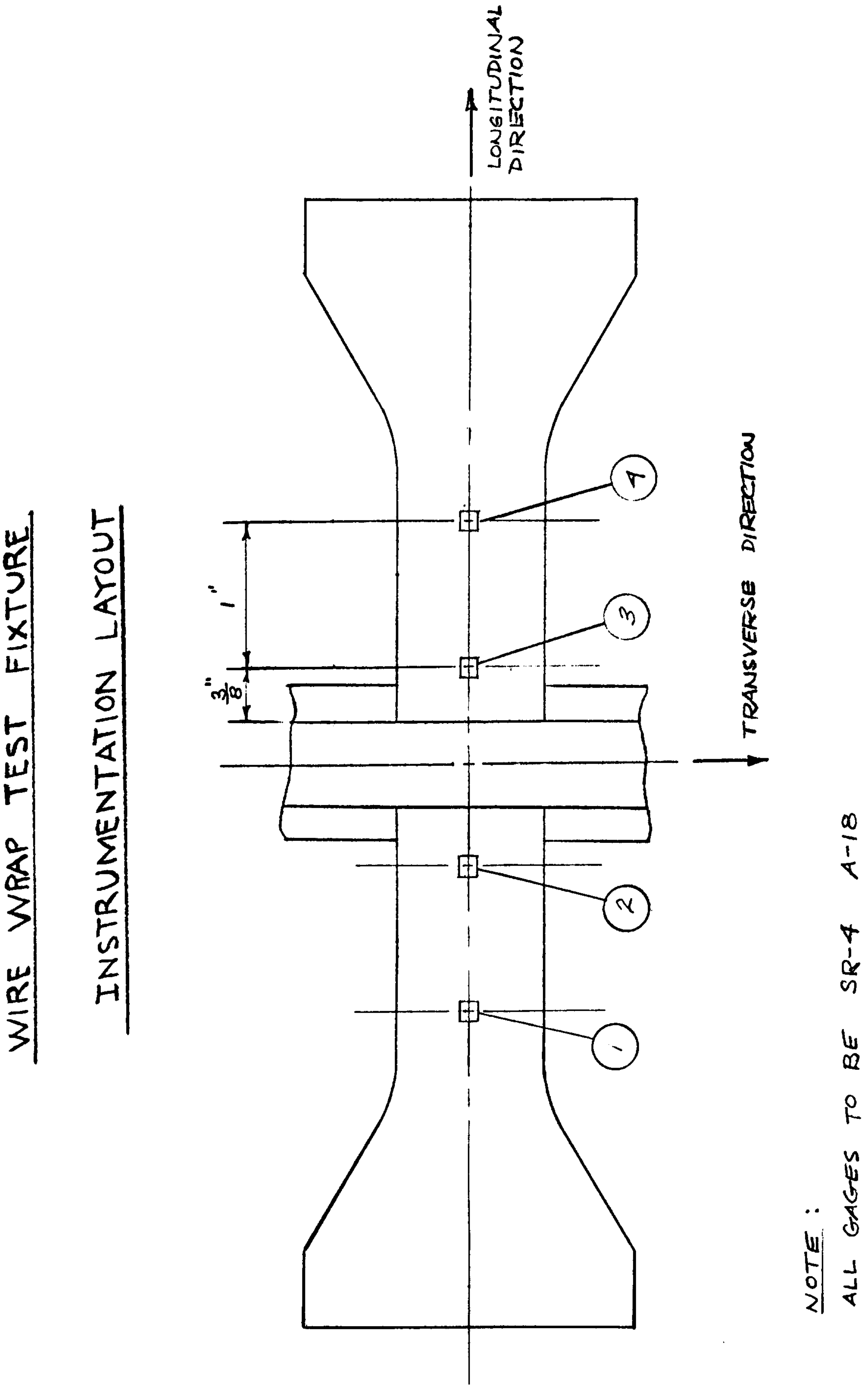
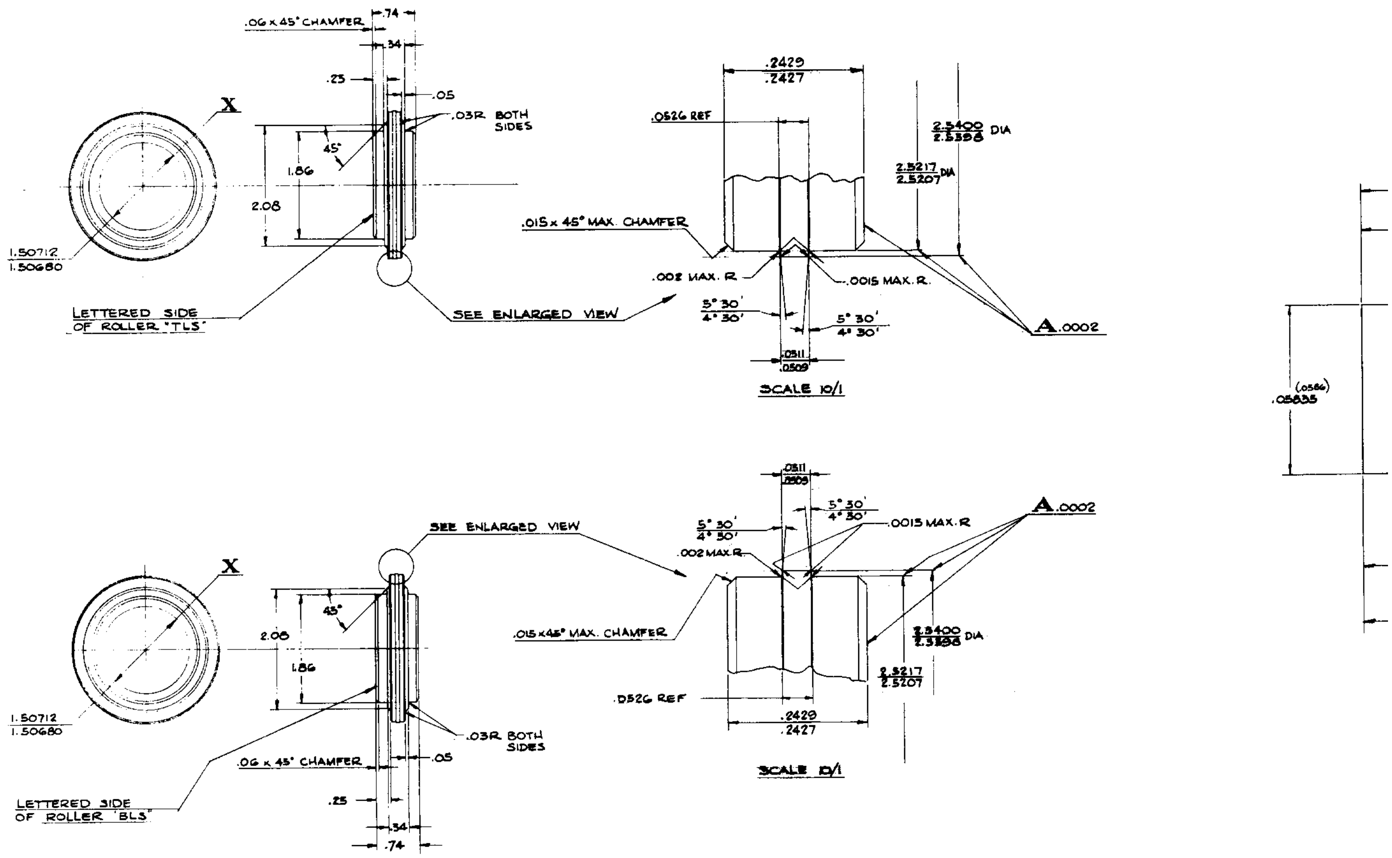
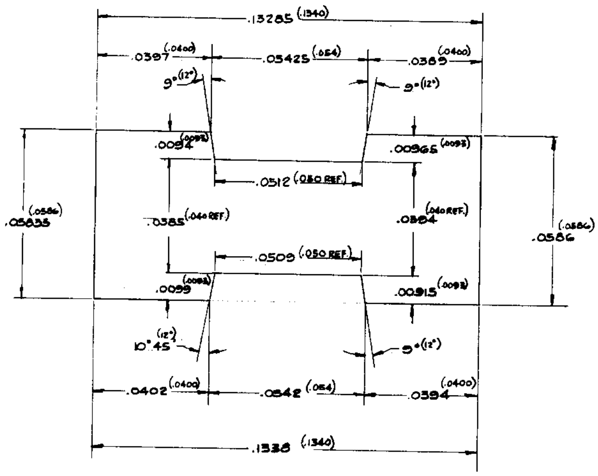

WIRE WRAP TEST FIXTURE
INSTRUMENTATION LAYOUT
LONGITUDINAL DIRECTION
TRANSVERSE DIRECTION
1"
3/8"
1
2
3
4
NOTE:
ALL GAGES TO BE SR-4 A-18

Figure 16


.06 x 45° CHAMFER
.74
.34
.25
.05
.03R BOTH SIDES
X
45°
1.86
2.08
1.50712
1.50680
LETTERED SIDE OF ROLLER "TLS"
SEE ENLARGED VIEW
.2429
.2427
.0526 REF
2.5400
2.5398 DIA
2.5217
2.5207 DIA
.015 x 45° MAX. CHAMFER
.002 MAX. R
.0015 MAX. R.
5° 30'
4° 30'
A .0002
.0511
.0509
SCALE 10/1
(.0586)
.05835
SEE ENLARGED VIEW
.015 x 45° MAX. CHAMFER
.0526 REF
LETTERED SIDE OF ROLLER "BLS"
.06 x 45° CHAMFER
SCALE 10/1

A.0002



A.0002

DIMENSIONS OF WIRE SAMPLE MADE
WITH ROLLERS SHOWN AT LEFT
(AVERAGE OF 2 SAMPLES)
DESIRED DIMENSIONS GIVEN IN PARENTHESES
SCALE 50/1

UNLESS OTHERWISE SPECIF

ITEM NO.	PART NO.	ASS'Y.	PART NO.	PART NO.
ADD			REFERENCE	CANCEL

SCALE 1/1

JOB NUMBER

STARTED 11/14/64

COMPLETED 11/14/64

CURTISS-WRIGHT CO...

WRIGHT AERONAUTICAL D...

WOOD-RIDGE, NEW JERSEY, U.S.A.

LS25754
SH. 4

UNLESS OTHERWISE SPECIFIED { ALL ANGLES ± 2°
FINISH DIMS ±.010
FINISH ALL OVER 32

A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED

FOR SIDE ROLLER DETAILS AND SECTION SHOWING ROLLERS IN ROLLING POSITION SEE LS 25754 SH 2

ITEM NO.	PART NO. ADD	ASS'Y.	PART NO. REFERENCE	PART NO CANCEL	D.W.N.	DESCRIPTION	INTERCH	MAT'L.	OTHER SPECS	FORG. CAST W.R.

PARTS LIST

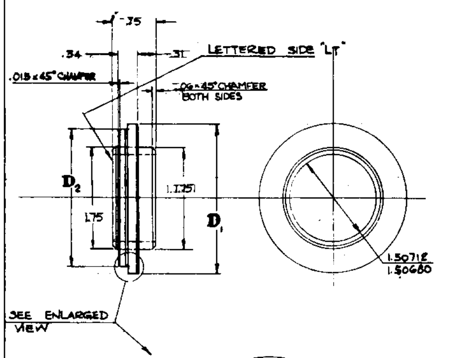
SCALE 1/1
JOB NUMBER
DRAWN BY Campbell
STARTED 11/14/60
COMPLETED 11/16/60

CURTISS-WRIGHT CORP.
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY, U.S.A.

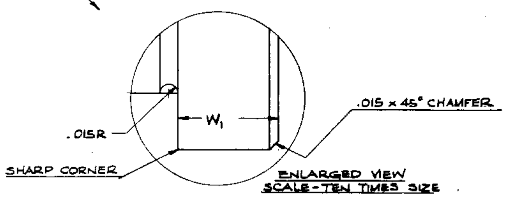
I WIRE ROLLERS - FINISH

LS25754
SH 4 OF 4 SHEETS

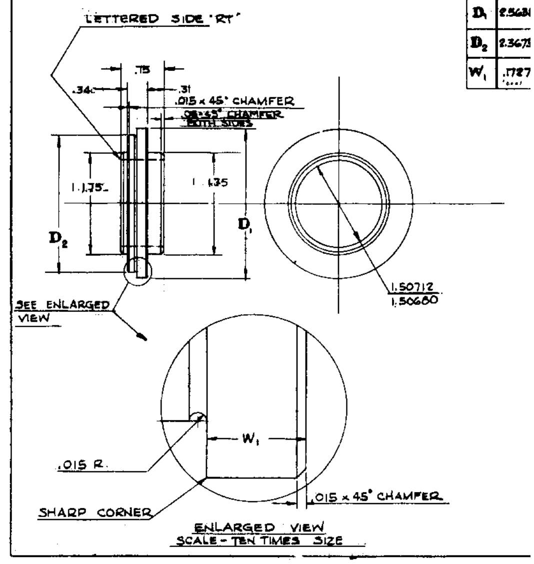
Figure 21



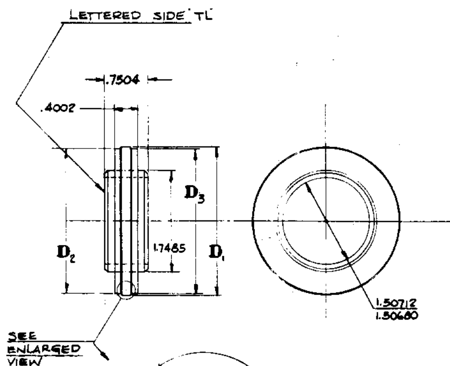
DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5637	~~2.5639 / 2.5637~~	
D_2	2.3677	~~2.3676 / 2.3672~~	
W_1	.17275	~~.1758 / .1726~~	



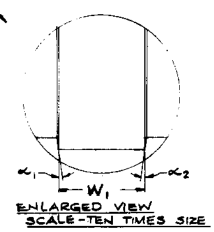
CHANNEL FORM ROLLER * XIII



DIMS	NO CHANGE
D_1	2.563
D_2	2.367
W_1	.1727

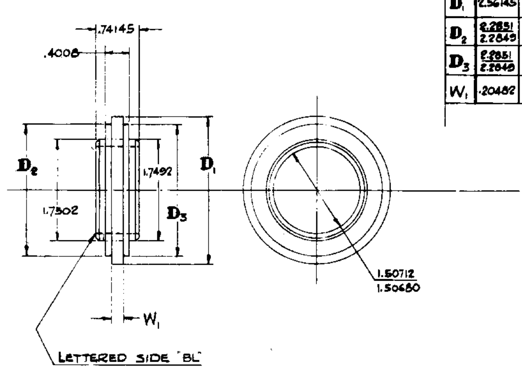


DIMS.	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5607 / 2.5606		
D_2	2.5191		
D_3	2.5191		
W_1	.1462		
α_1	7°30'		
α_2	7°30'		



CHANNEL FORM ROLLER * V

DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.56145		
D_2	2.2851 / 2.2849		
D_3	2.2851 / 2.2849		
W_1	.20482		



CHANNEL FORM ROLLER * I

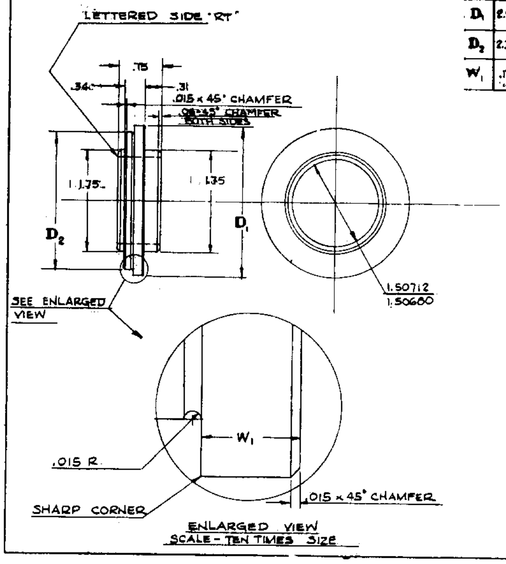
LETTER

LETTERED SIDE "LT"

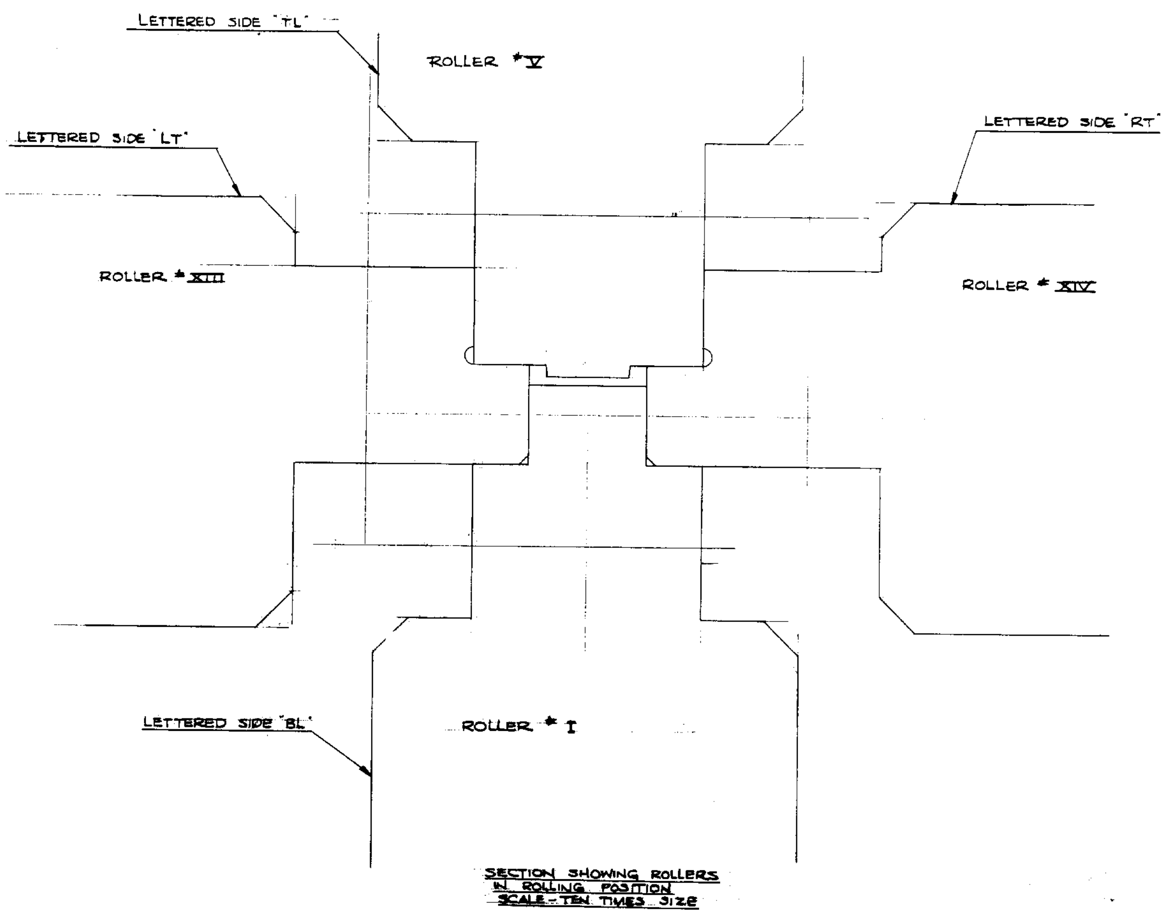
ROLLER *

LETT

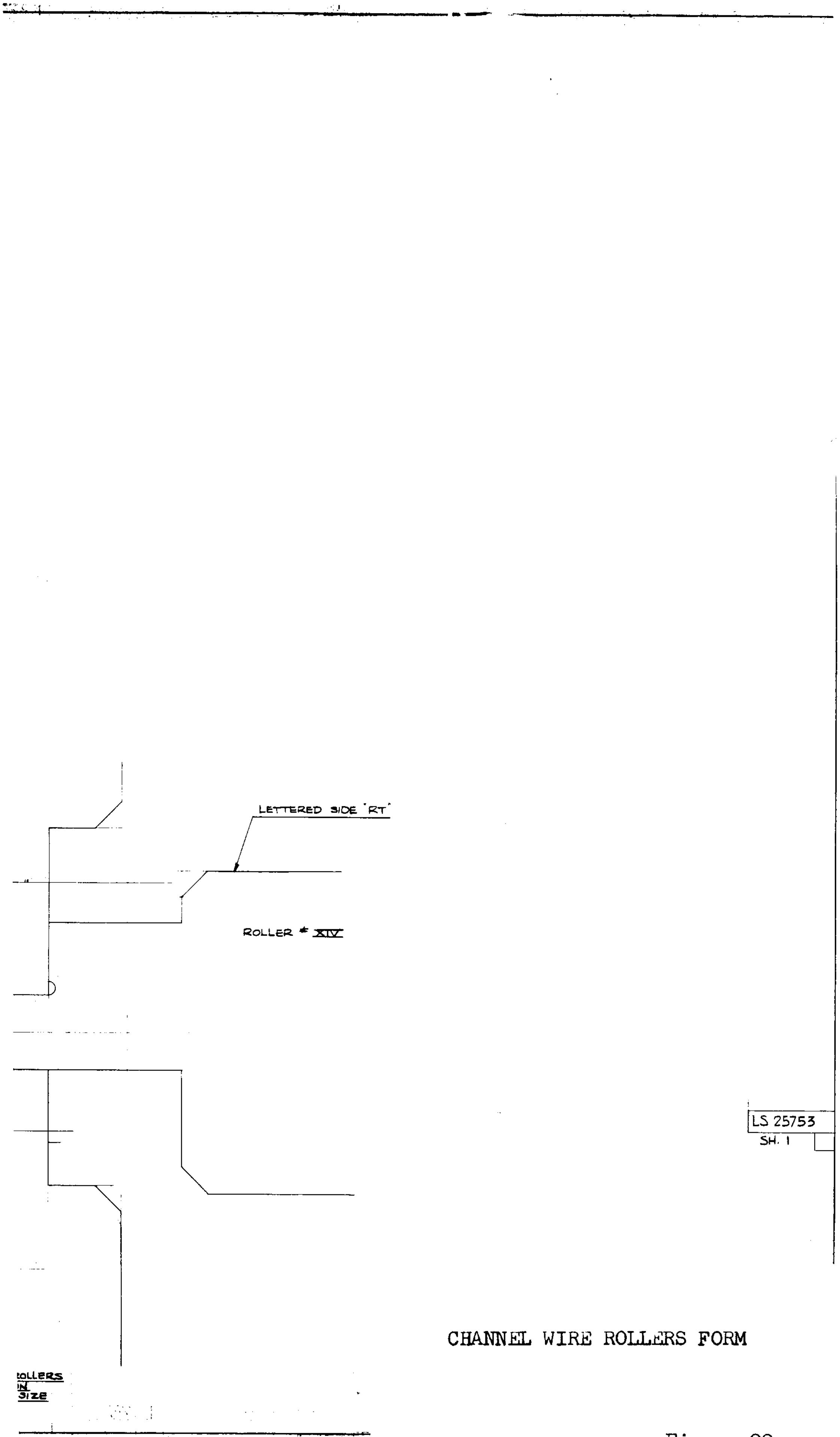
DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5638	2.5639/2.5633	
D_2	2.3675	2.3675/2.3674	
W_1	.1727	.1728/.1726	



CHANNEL FORM ROLLER # XIV



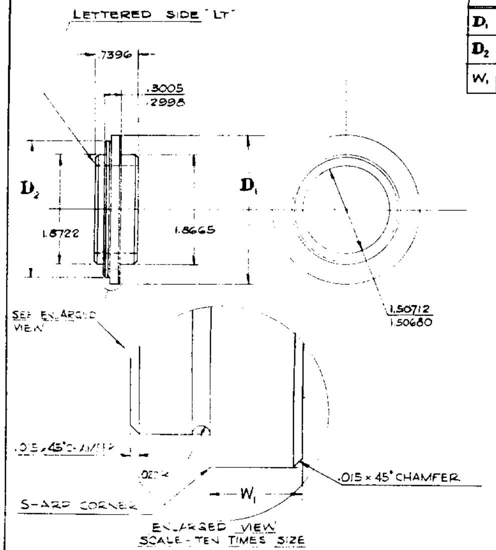
SECTION SHOWING ROLLERS IN ROLLING POSITION
SCALE - TEN TIMES SIZE



CHANNEL WIRE ROLLERS FORM

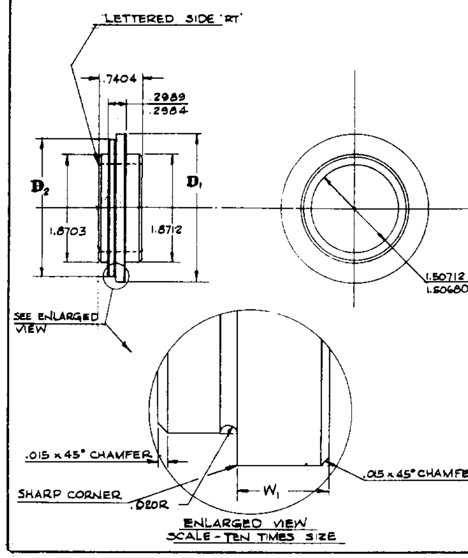
Figure 22

DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.3592		
D_2	2.3568		
W_1	.1598		

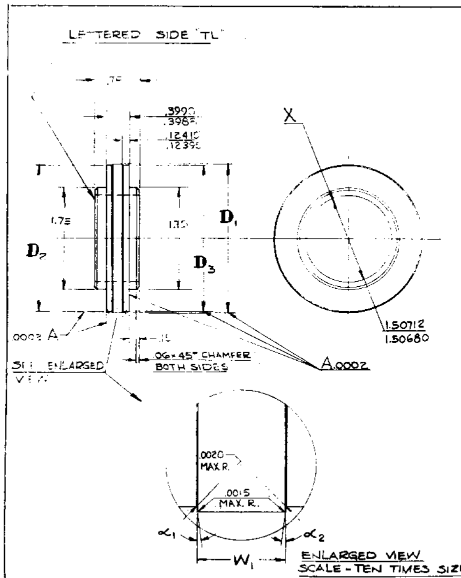


CHANNEL FINISH ROLLER # XVI

DIMS.	NO CHANGE	CH
D_1	2.5568	
D_2	2.3552	
W_1	.1600	



DIMS	NO CHANGE	CHANGE	CHANGE
D_1	2.5573 / 2.5571		
D_2	2.5392		
D_3	2.5392		
W_1	.1493		
α_1	7°30'		
α_2	7°30'		



A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED

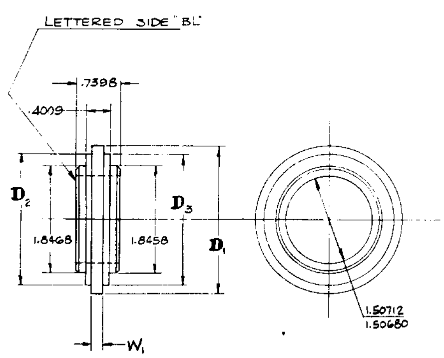
ALL NOTES APPLY UNLESS OTHERWISE SPECIFIED

FINISHED DIM ±.010
ALL ANGLES ± 2°
FINISH ALL OVER

LS 25753-4

CHANNEL FINISH ROLLER # IV

DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5477 / 2.5476		
D_2	2.27772		
D_3	2.27772		
W_1	.19995		



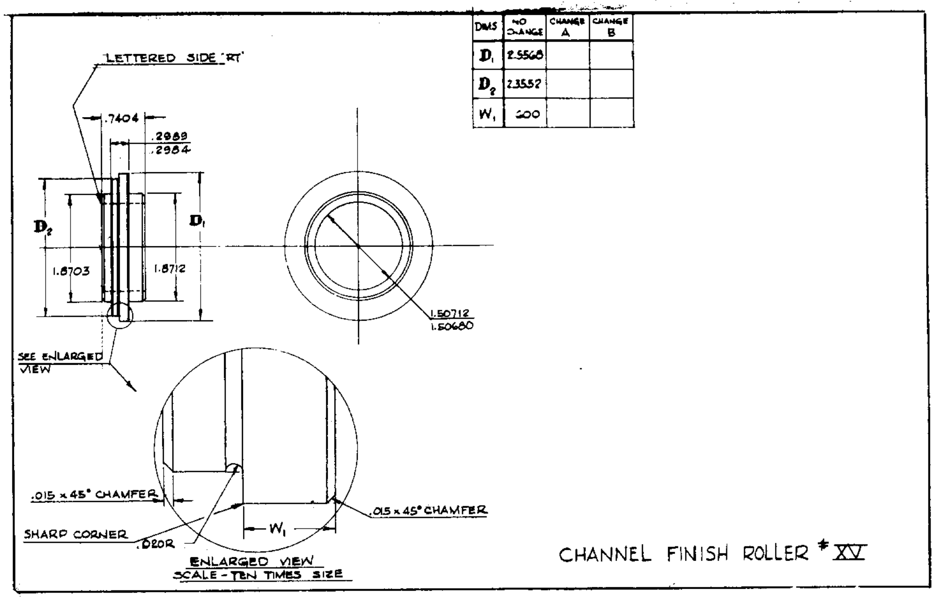
CHANNEL FINISH ROLLER # II

LETTERED SI

LETTERED SIDE "LT"

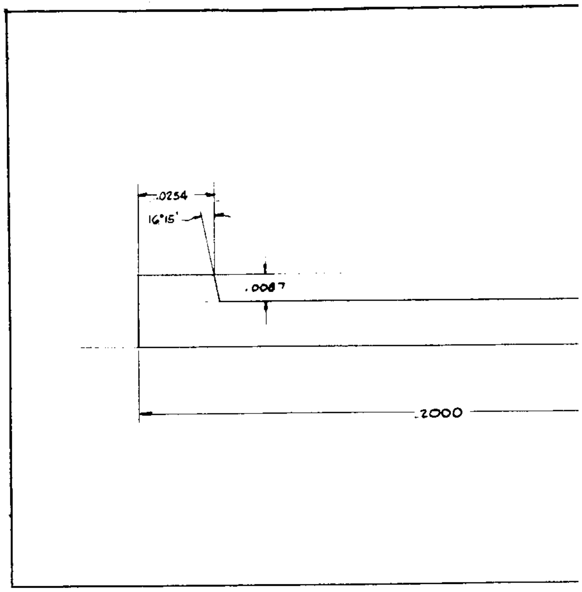
ROLLER #

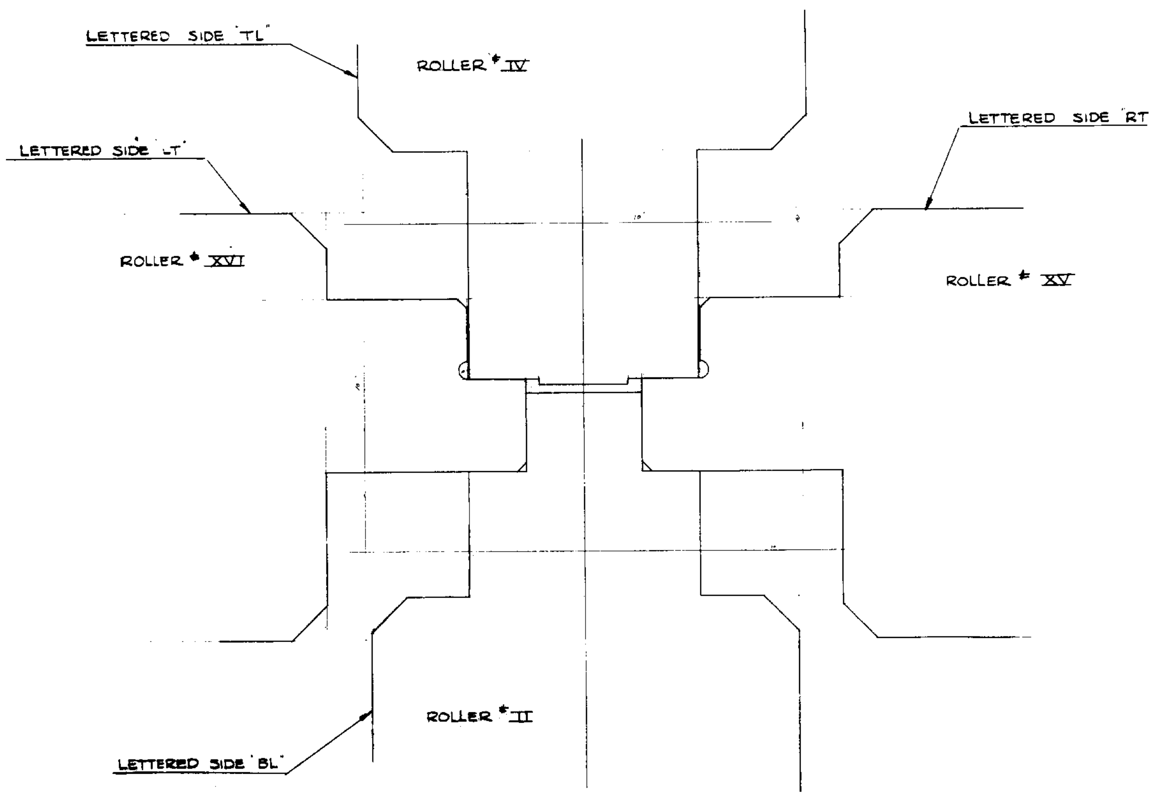
LETTERED



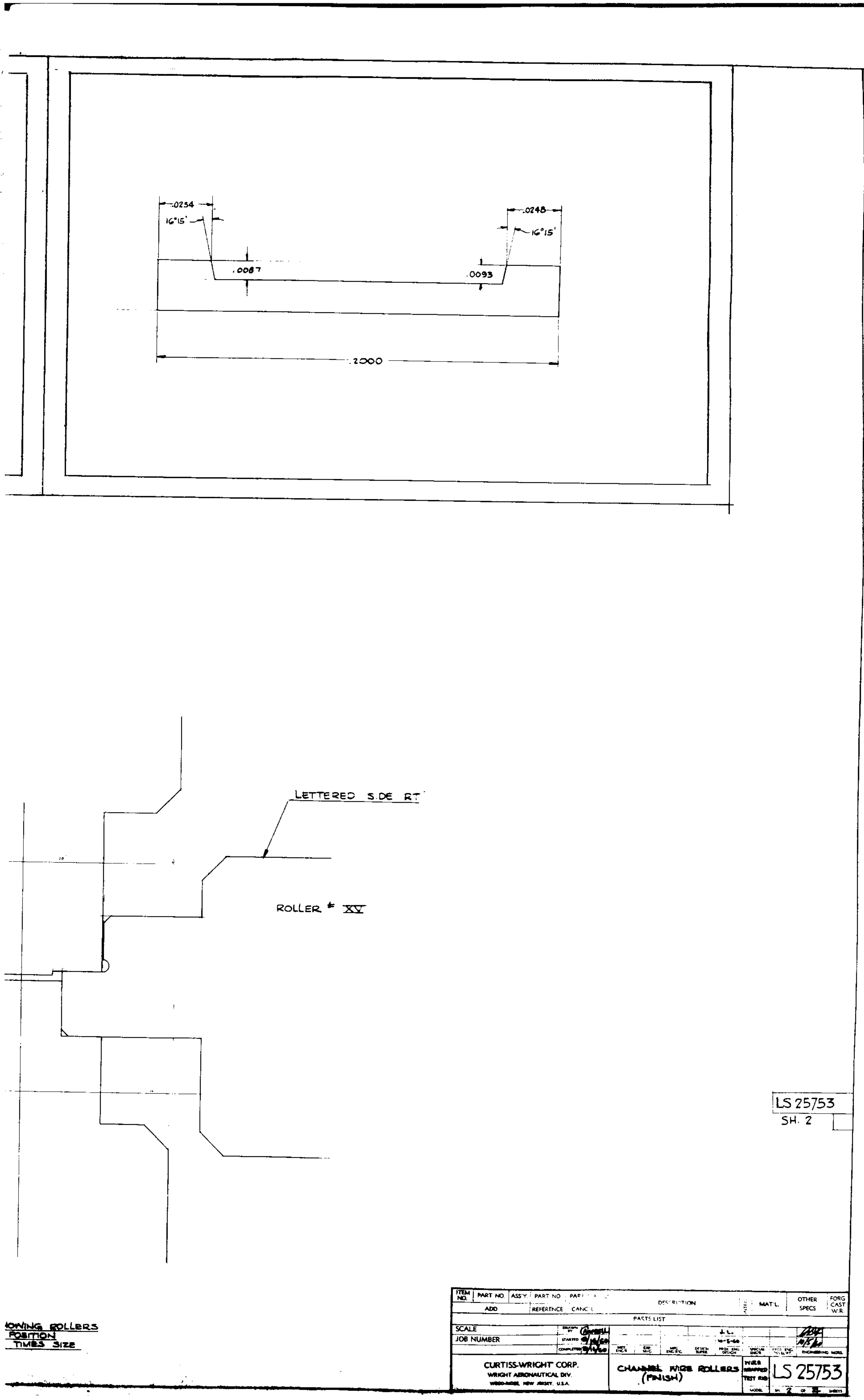
DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5568		
D_2	2.3552		
W_1	.200		

CHANNEL FINISH ROLLER # XV



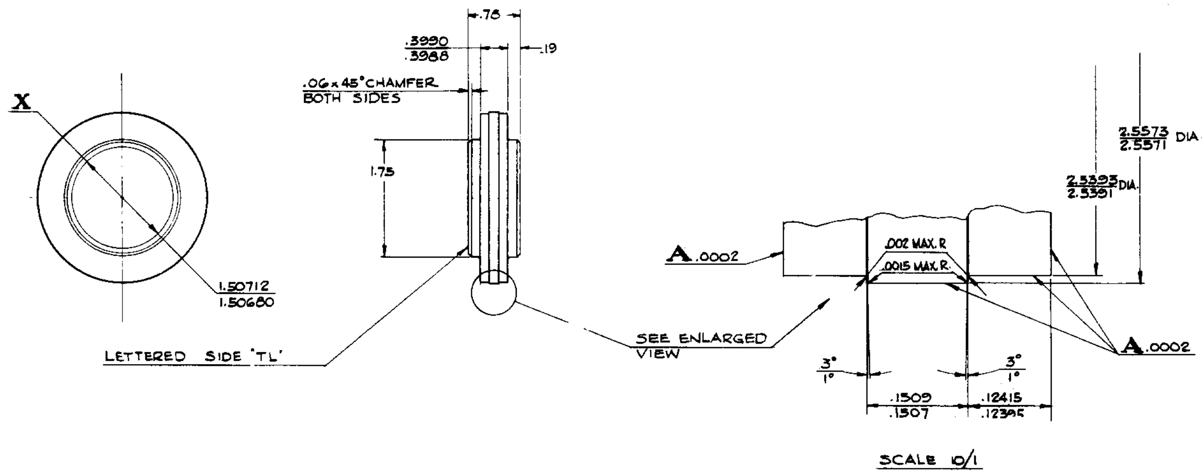


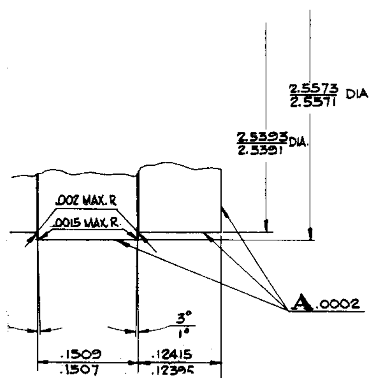
SECTION SHOWING ROLLERS
IN ROLLING POSITION
SCALE - TEN TIMES SIZE



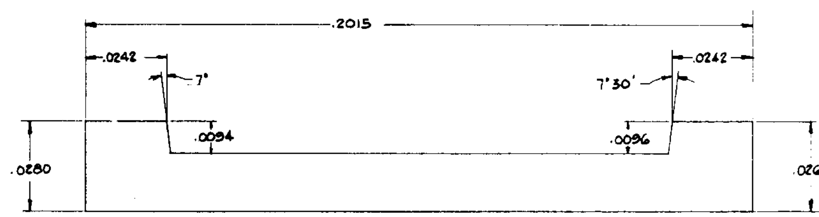
.0254
16°15'
.0248
16°15'
.0087
.0093
.2000
LETTERED SIDE RT
ROLLER # XV
LS 25753
SH. 2
ROLLERS
POSITION
TIMES SIZE
ITEM NO.
PART NO.
ASS'Y PART NO.
ADD
REFERENCE
DESCRIPTION
MAT'L
OTHER SPECS
PARTS LIST
SCALE
JOB NUMBER
CURTISS-WRIGHT CORP.
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY, U.S.A.
CHANNEL WIRE ROLLERS (FINISH)
WIRE WRAPPED TEST RIG
LS 25753

Figure 23


X
1.50712
1.50680
.78
.3990
.3988
.19
.06 x 45° CHAMFER
BOTH SIDES
1.75
LETTERED SIDE 'TL'
SEE ENLARGED
VIEW
2.5573
2.5571 DIA
2.5393
2.5391 DIA
A .0002
.002 MAX. R
.0015 MAX. R
A .0002
3°
1°
3°
1°
.1509
.1507
.12415
.12395
SCALE 10/1



SCALE 10/1



UNLESS OTHERWISE SPECIFIED { ALL ANGL
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FINISH A

A SURFA
AROUND C
TO A COM
MOUNTED
BE WITHIN
READING S

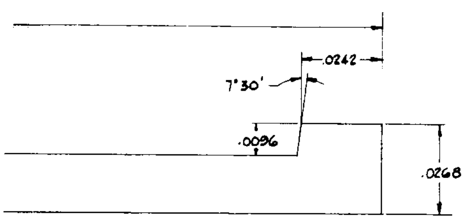
FOR SIDE
DETAILS A
ROLLERS
SEE LS 2

MILITARY SPECIFICATIONS	
SPEC NUMBERS	DEVIATIONS

CURTISS-WRIGHT CORP
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY, U.S.A.

CHANNEL WI
FINISH

Fi



LS 25753

SH. 3

UNLESS OTHERWISE SPECIFIED
- ALL ANGLES ±2°
- FINISH DIMS ±.010
- FINISH ALL OVER $\overset{32}{\surd}$

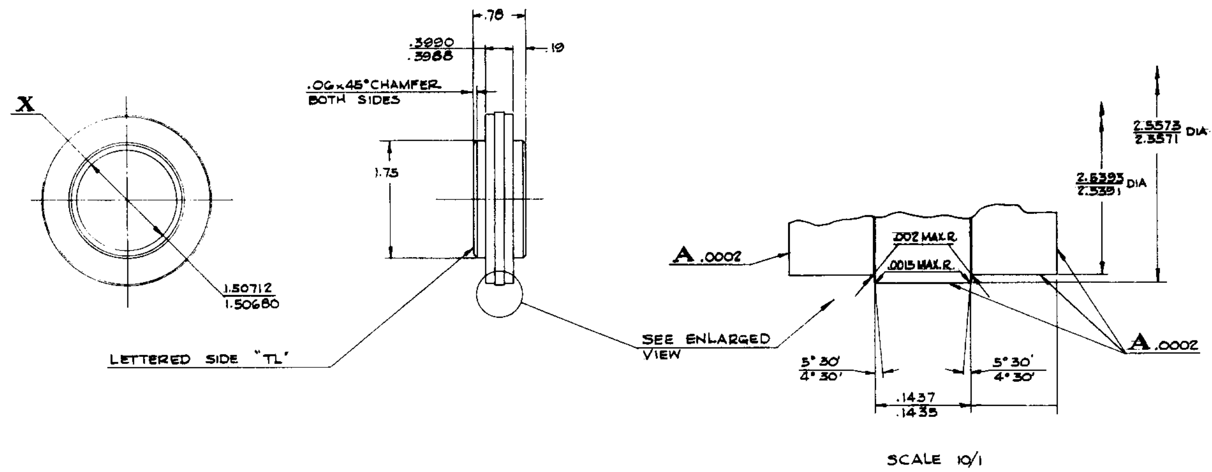
A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED

FOR SIDE ROLLER & BOTTOM ROLLER DETAILS AND SECTION SHOWING ROLLERS IN ROLLING POSITION SEE LS 25753 SH 2.

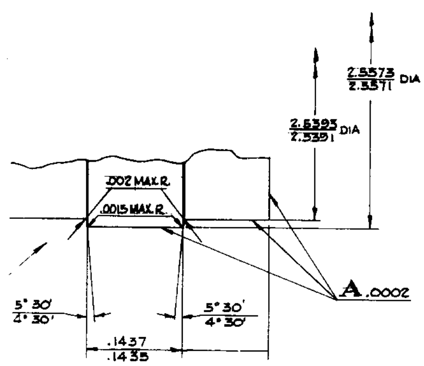
MILITARY SPECIFICATIONS							
SPEC. NUMBERS	DEVIATIONS	Campbell DRAWN BY 11/14/60	CHECKER	DESIGN SUPER	PROJ. ENG. DESIGN	PROJ. ENG. DEVEL'PT	PROJ. ENG. RESEARCH
		STARTED 4/15/60					
		COMPL'TD	ENGINEERING			ASST CHIEF ENGINEER	CHIEF ENGINEER

CURTISS-WRIGHT CORP WRIGHT AERONAUTICAL DIV. WOOD-RIDGE, NEW JERSEY, U. S. A.	CHANNEL WIRE ROLLERS-FINISH	MODEL	LS25753 SH 3 OF 4 SHEETS

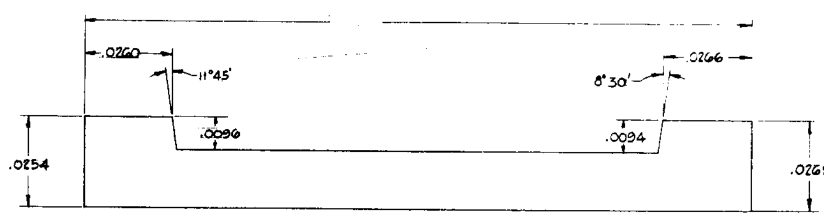
Figure 24



X
1.50712
1.50680
.78
.3990
.3988
.19
.06×45°CHAMFER
BOTH SIDES
1.75
LETTERED SIDE "TL"
SEE ENLARGED VIEW
A .0002
.002 MAX R.
.0015 MAX R.
2.5573
2.5571 DIA
2.5393
2.5391 DIA
A .0002
5°30'
4°30'
5°30'
4°30'
.1437
.1435
SCALE 10/1



SCALE 10/1



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READ

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DETAI
ROLLE
SEE

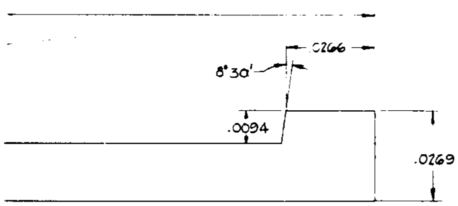
MILITARY SPECIFICATIONS

DEVIATIONS

CURTISS-WRIGHT CORP
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY, U.S.A.

CHAN

Figur
35



LS 25753
SH. 4

UNLESS OTHERWISE SPECIFIED
ALL ANGLES ±2°
FINISH DIMS ±.010
FINISH ALL OVER 32√

A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED

FOR SIDE ROLLER & BOTTOM ROLLER DETAILS AND SECTION SHOWING ROLLERS IN ROLLING POSITION SEE LS 25753 SH. 2

MILITARY SPECIFICATIONS		DRAWN BY					
SPEC NUMBERS	DEVIATIONS	11/17/60	CHECKER	DESIGN SUPER	PROJ. ENG. DESIGN	PROJ. ENG. DEVEL'PT	PROJ. ENG. RESEARCH
		STARTED 11/11/60					
		COMPL'TD	ENGINEERING MGRS		M. MECH.	ASS'T. CHIEF ENGINEER	CHIEF ENGINEER

CURTISS-WRIGHT CORP
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY, U.S.A.

CHANNEL WIRE ROLLERS-FINISH

LS25753
SH 4 OF 4 SHEETS

Figure 25

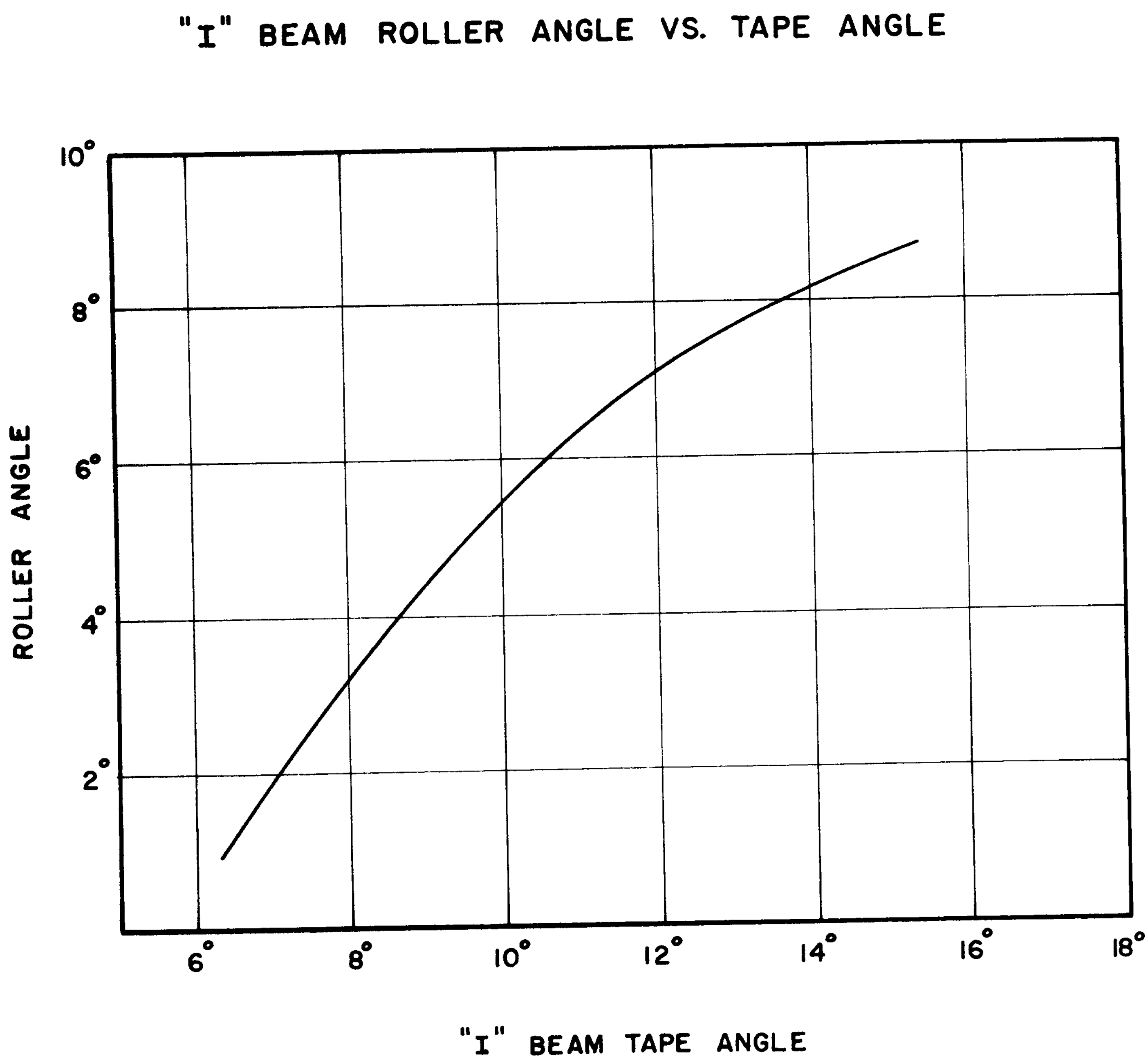
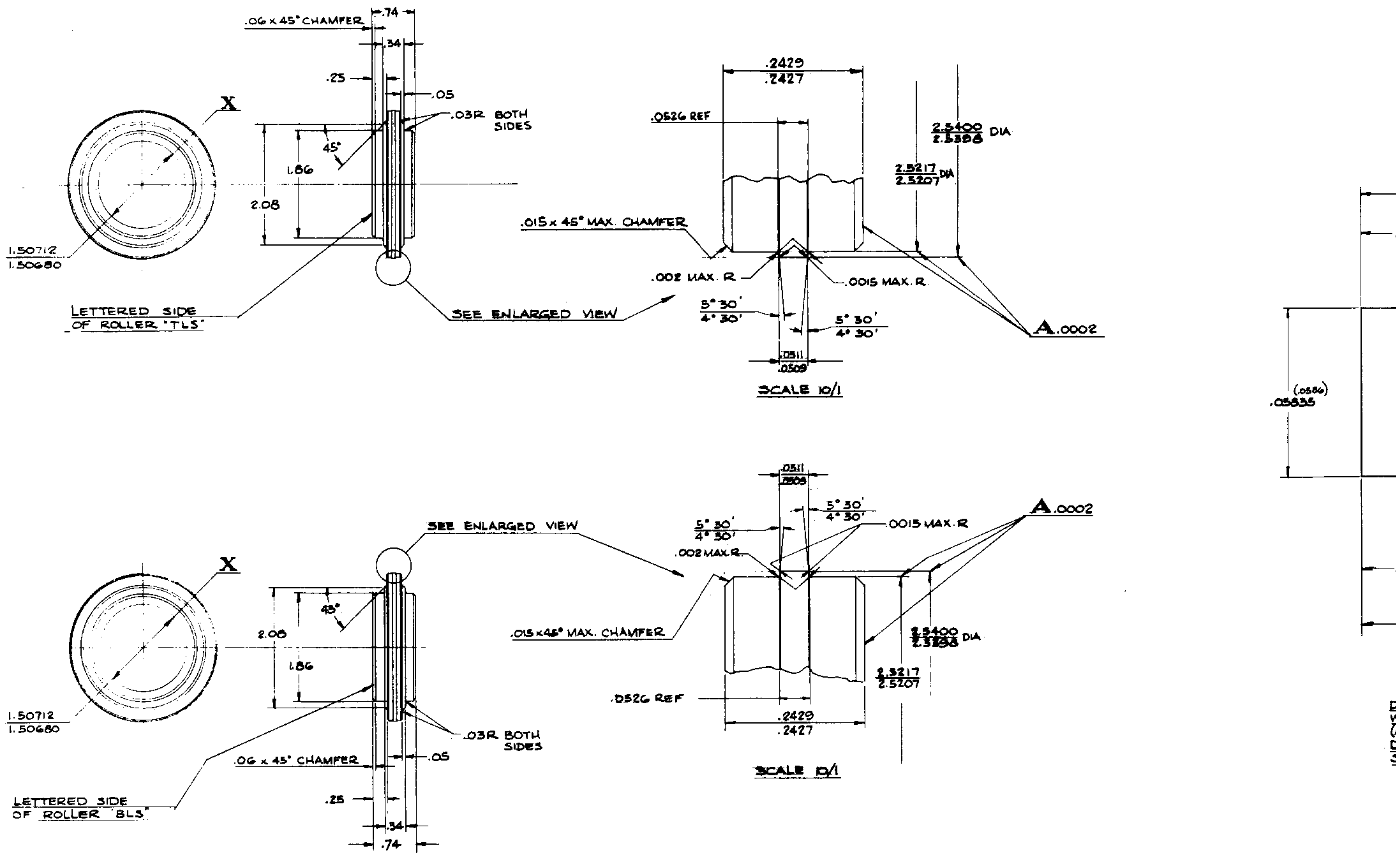

"I" BEAM ROLLER ANGLE VS. TAPE ANGLE
10°
8°
6°
4°
2°
ROLLER ANGLE
6°
8°
10°
12°
14°
16°
18°
"I" BEAM TAPE ANGLE

Figure 20

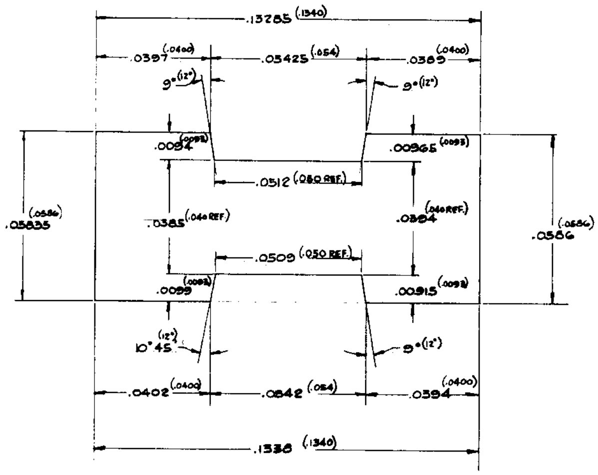


.06 x 45° CHAMFER
.74
.34
.25
.05
.03R BOTH SIDES
X
45°
1.86
2.08
1.50712
1.50680
LETTERED SIDE OF ROLLER "TLS"
SEE ENLARGED VIEW
.2429
.2427
.0526 REF
2.5400
2.5388 DIA
2.5217
2.5207 DIA
.015 x 45° MAX. CHAMFER
.002 MAX. R
.0015 MAX. R
5° 30'
4° 30'
.0311
.0309
A .0002
SCALE 10/1
LETTERED SIDE OF ROLLER "BLS"
.015 x 45° MAX. CHAMFER
.0526 REF
(.0586)
.05835

A

A.0002

A.0002



DIMENSIONS OF WIRE SAMPLE MADE
WITH ROLLERS SHOWN AT LEFT
(AVERAGE OF 2 SAMPLES)
DESIRED DIMENSIONS GIVEN IN PARENTHESES
SCALE 50/1

UNLESS OTHERWISE SPECIFI

ITEM NO.	PART NO.	ASS'Y.	PART NO.	PART NO.
ADD			REFERENCE	CANCEL

SCALE 1/1

JOB NUMBER

STARTED 11/14/6·

COMPLETED 11/18/6·

MET. ENG'R.

CURTISS-WRIGHT CO...

WRIGHT AERONAUTICAL DIV.

WOOD-RIDGE, NEW JERSEY, U.S.A.

I

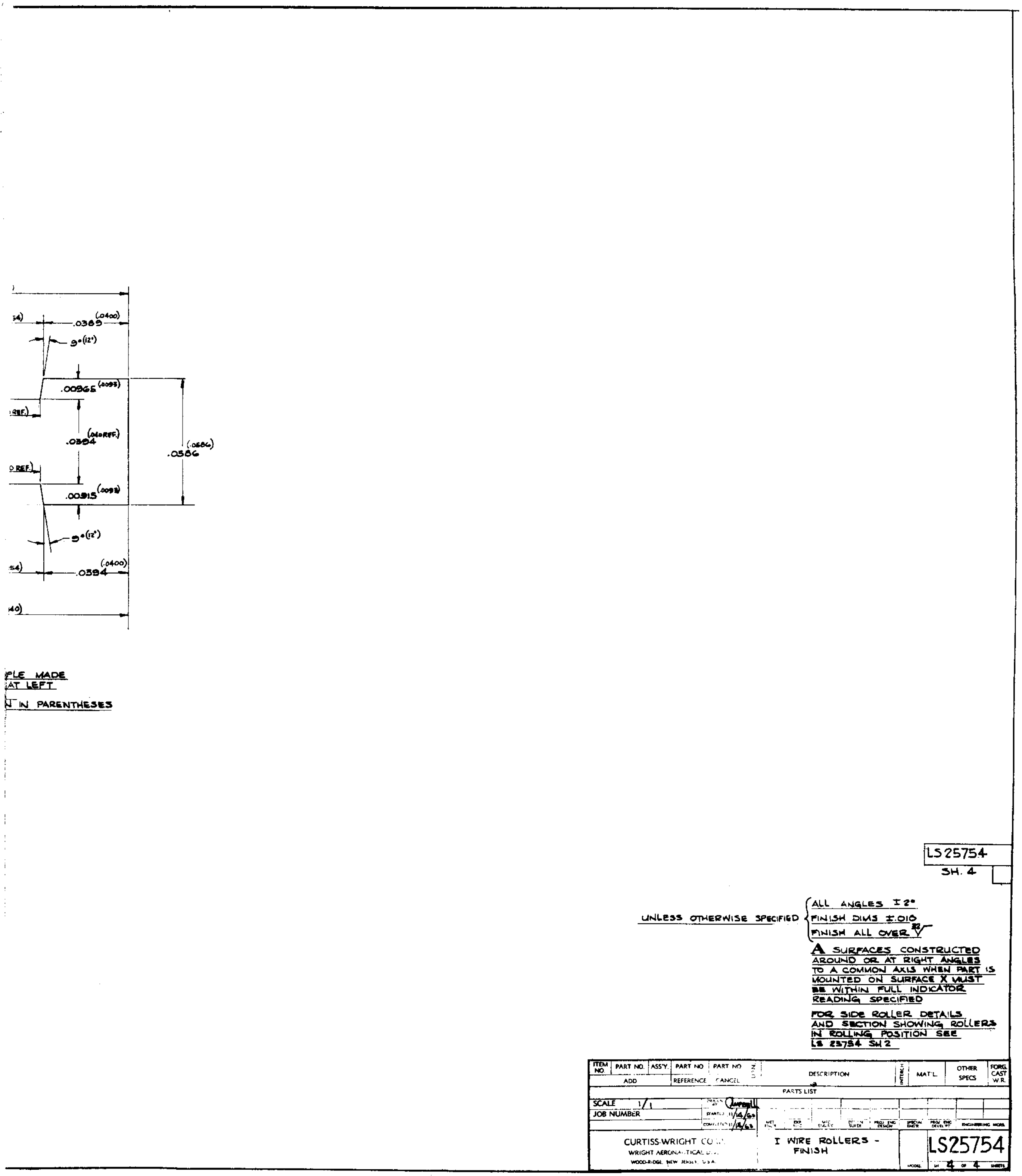
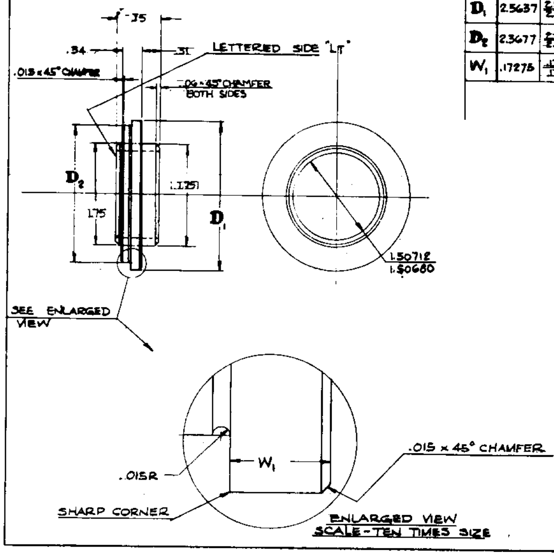

.0389 (.0400)
9° (12°)
.00965 (.0093)
.0304 (.040 REF.)
.0586 (.0686)
.00915 (.0093)
9° (12°)
.0394 (.0400)
PLE MADE
AT LEFT
N IN PARENTHESES
LS 25754
SH. 4
UNLESS OTHERWISE SPECIFIED
ALL ANGLES ± 2°
FINISH DIMS ±.010
FINISH ALL OVER
A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED
FOR SIDE ROLLER DETAILS AND SECTION SHOWING ROLLERS IN ROLLING POSITION SEE LS 25754 SH 2
ITEM NO
PART NO.
ASS'Y.
PART NO
PART NO
ADD
REFERENCE
CANCEL
DESCRIPTION
MAT'L.
OTHER SPECS
FORG. CAST W.R.
PARTS LIST
SCALE 1/1
JOB NUMBER
CURTISS-WRIGHT CO.
I WIRE ROLLERS - FINISH
LS25754
4 OF 4

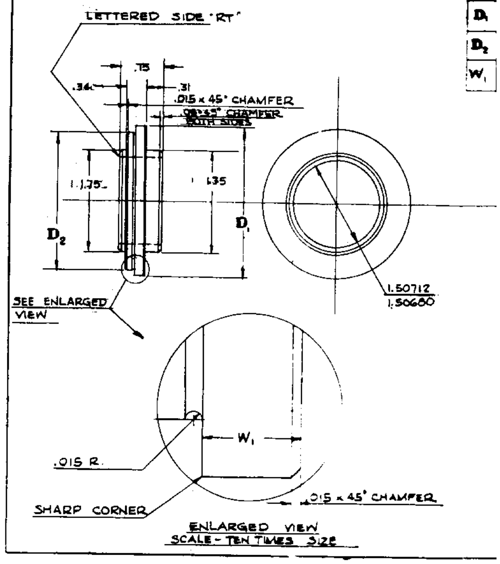
Figure 21

DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5637	2.5639 / 2.5637	
D_2	2.3677	2.3674 / 2.3672	
W_1	.17275	.1728 / .1726	

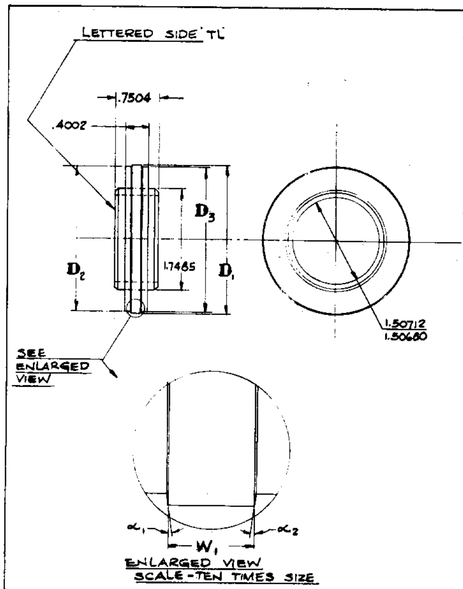


CHANNEL FORM ROLLER # XIII

DIMS			
D_1			
D_2			
W_1			

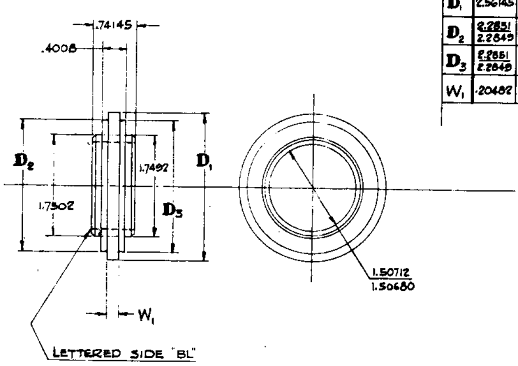


DIMS.	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5607 / 2.5606		
D_2	2.5191		
D_3	2.5191		
W_1	.1462		
α_1	7°80'		
α_2	7°30'		



CHANNEL FORM ROLLER # V

DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.56145		
D_2	2.2851 / 2.2849		
D_3	2.2851 / 2.2849		
W_1	.20482		

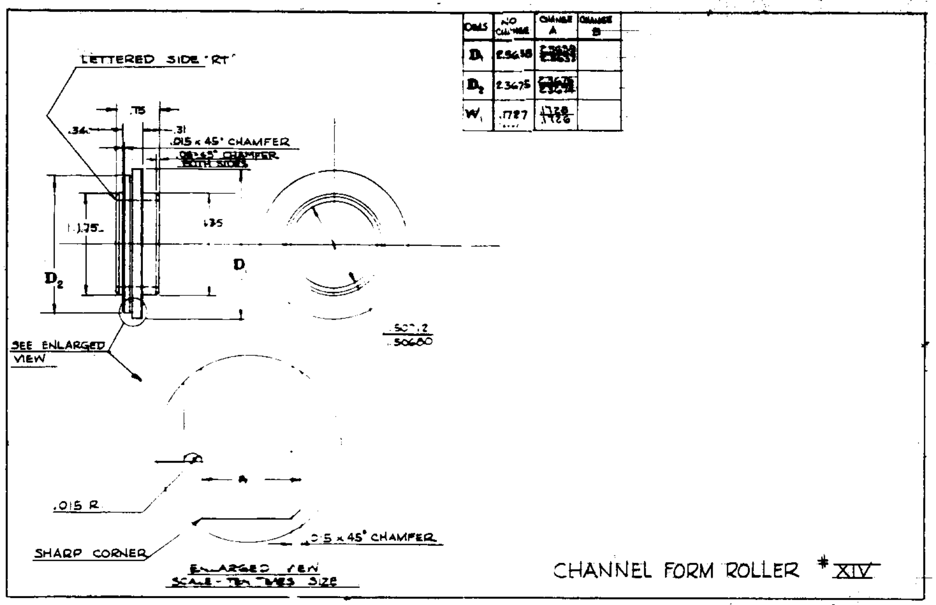


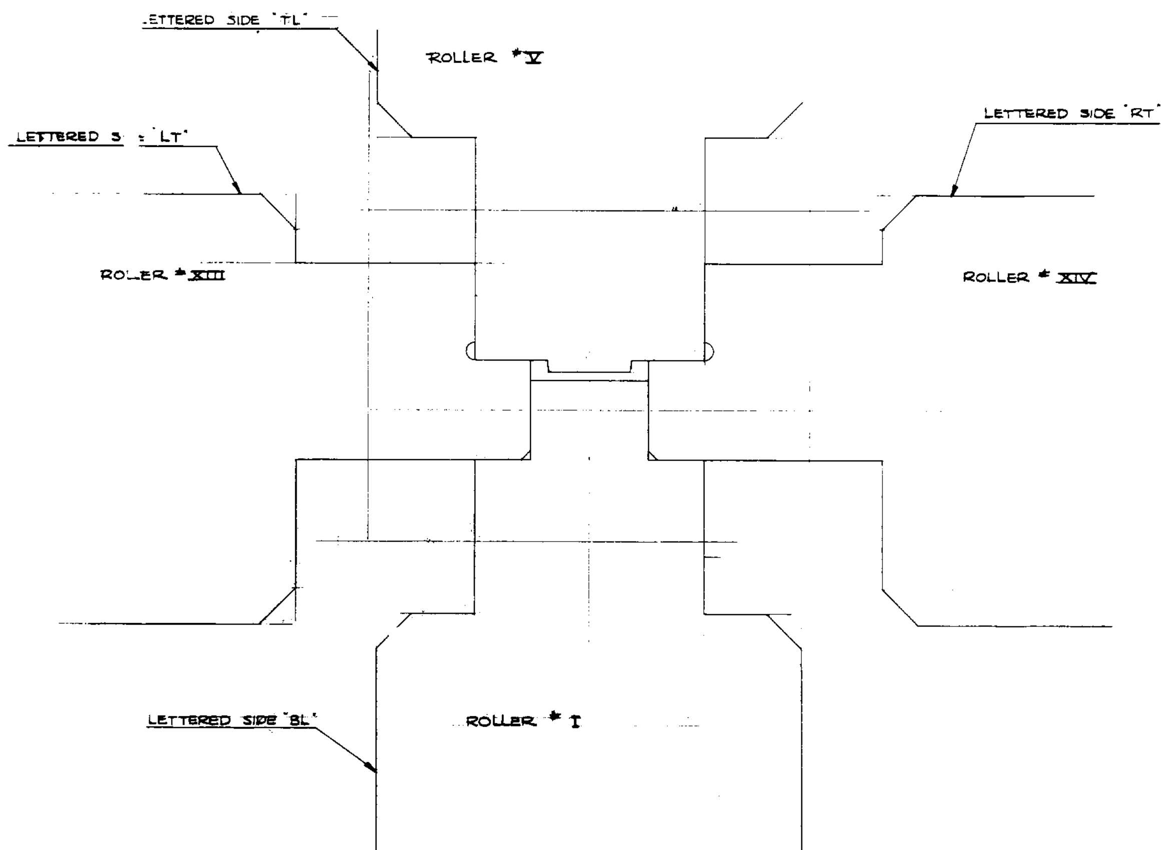
CHANNEL FORM ROLLER # I

LETTERED S

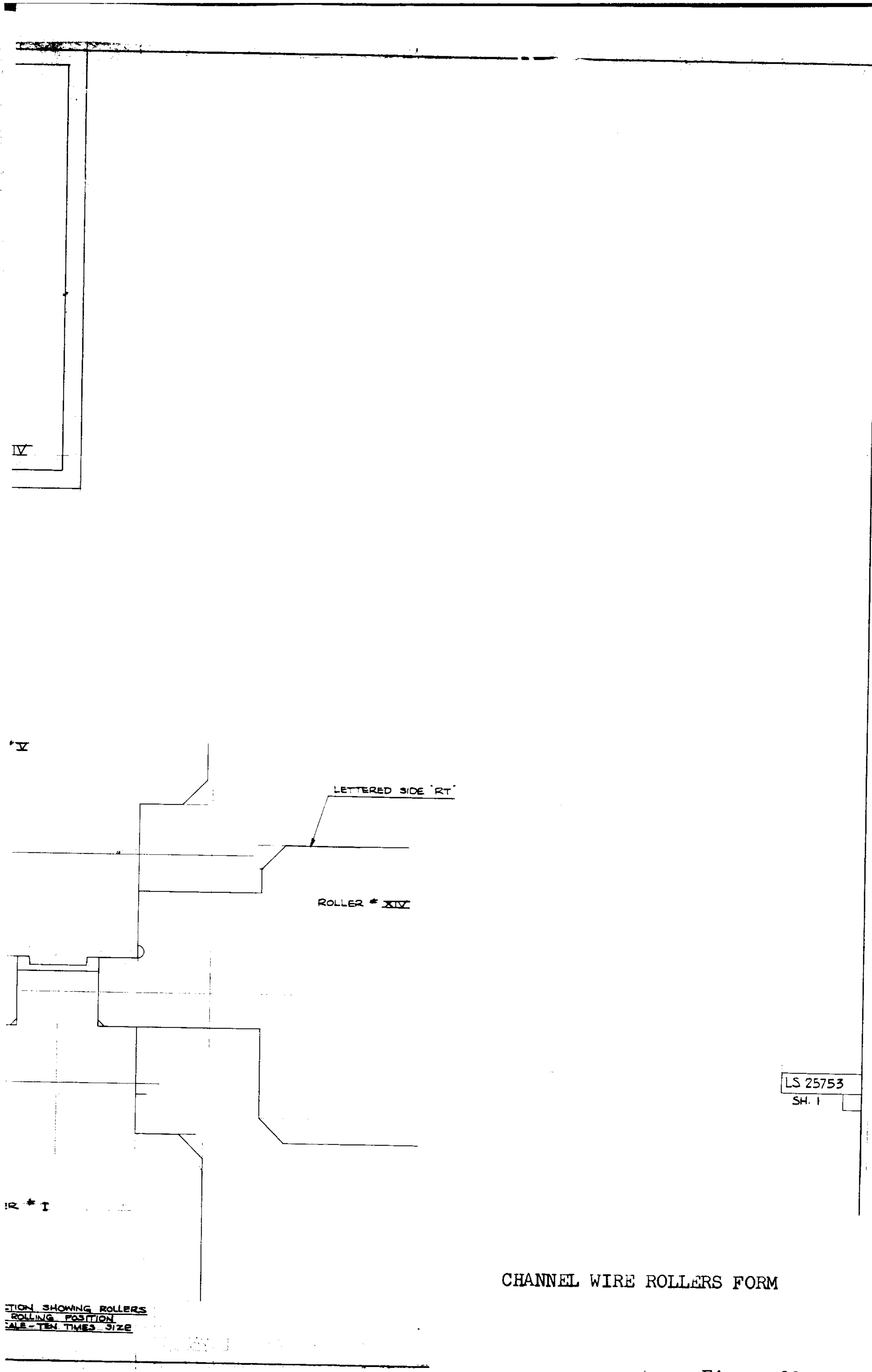
ROLLER

LET



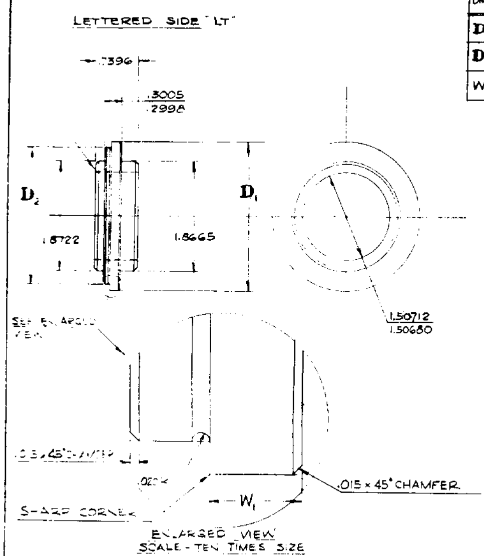


SECTION SHOWING ROLLERS
IN ROLLING POSITION
SCALE - TEN TIMES SIZE



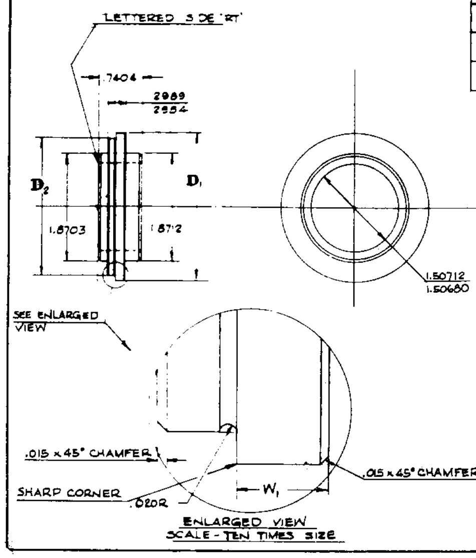
CHANNEL WIRE ROLLERS FORM

Figure 22



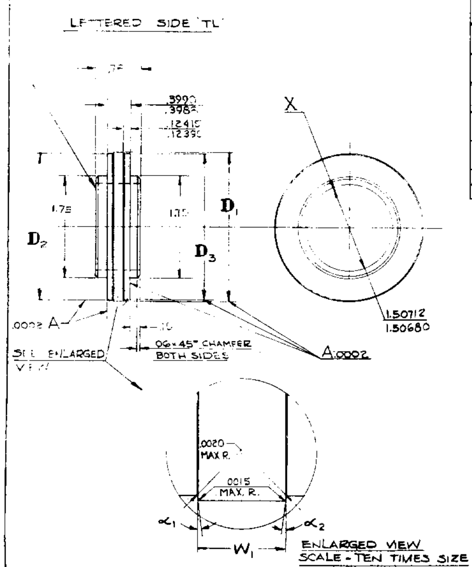
DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5592		
D_2	2.3568		
W_1	.1598		

CHANNEL FINISH ROLLER # XVI



DIMS	NO CHANGE	CHANGE A
D_1	2.5568	
D_2	2.3552	
W_1	.1600	

C



J.L. 10-15-56

DIMS	NO CHANGE	CHANGE	CHANGE
D_1	2.5573 / 2.5571		
D_2	2.5392		
D_3	2.5392		
W_1	.1493		
α_1	7°30'		
α_2	7°30'		

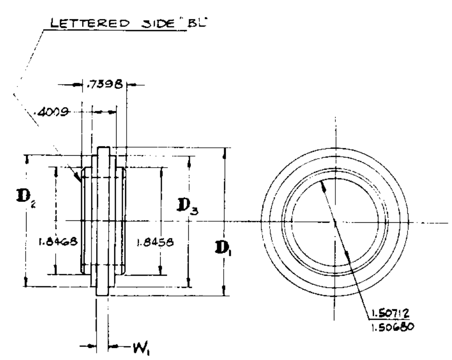
A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED

ALL NOTES APPLY UNLESS OTHERWISE SPECIFIED

FINISHED DIM ±.010
ALL ANGLES ± 2°
FINISH ALL OVER 32

LS 25753-4

CHANNEL FINISH ROLLER # IV



DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5477 / 2.5476		
D_2	2.27772		
D_3	2.27772		
W_1	.19995		

CHANNEL FINISH ROLLER # II

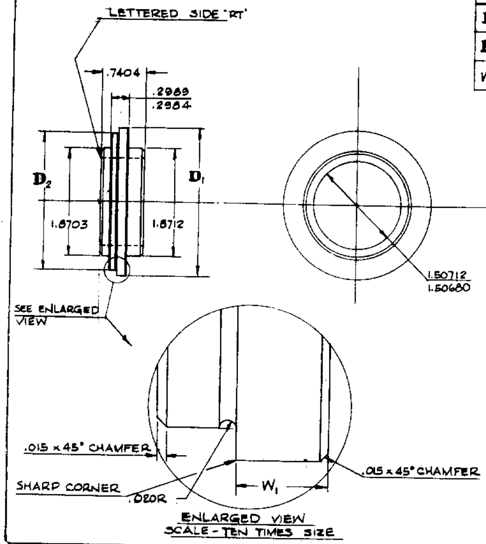
LETTERED SID

LETTERED SIDE 'LT'

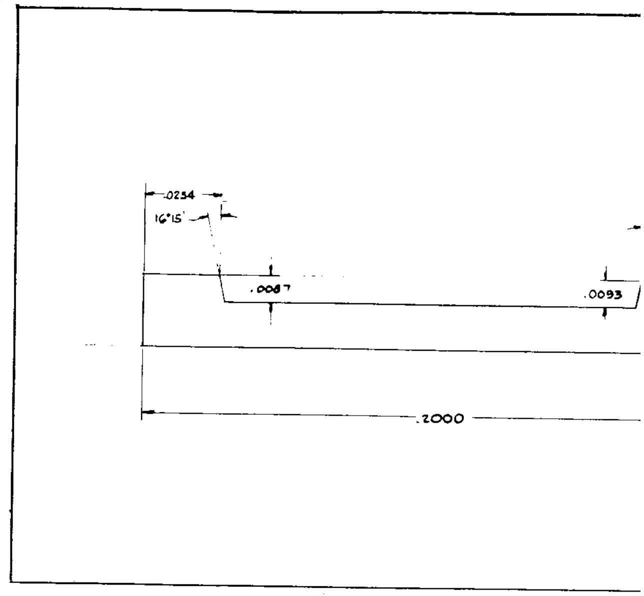
ROLLER # X

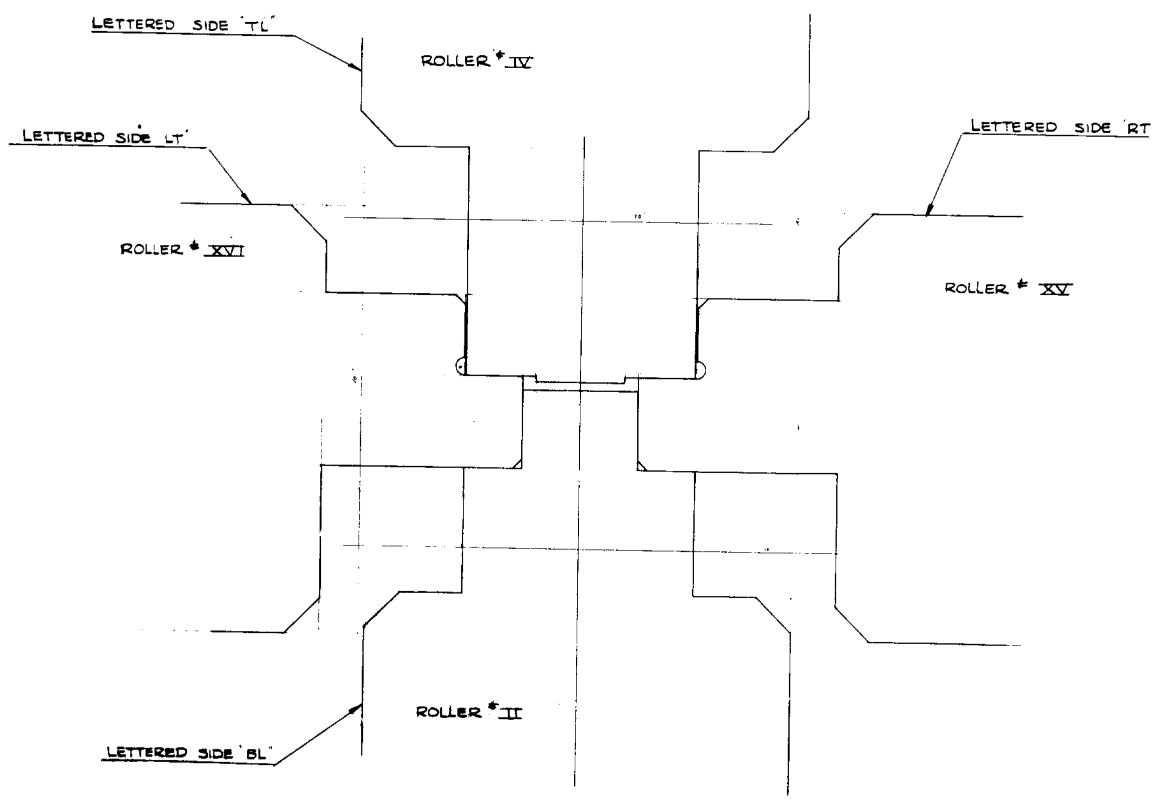
LETTERED SI

DIMS	NO CHANGE	CHANGE A	CHANGE B
D_1	2.5568		
D_2	2.3532		
W_1	.600		



CHANNEL FINISH ROLLER # XV





SECTION SHOWING ROLLERS
IN ROLLING POSITION
SCALE - TEN TIMES SIZE

ITEM NO.	PART NO
	ADD

SCALE
JOB NUMBER

CURT

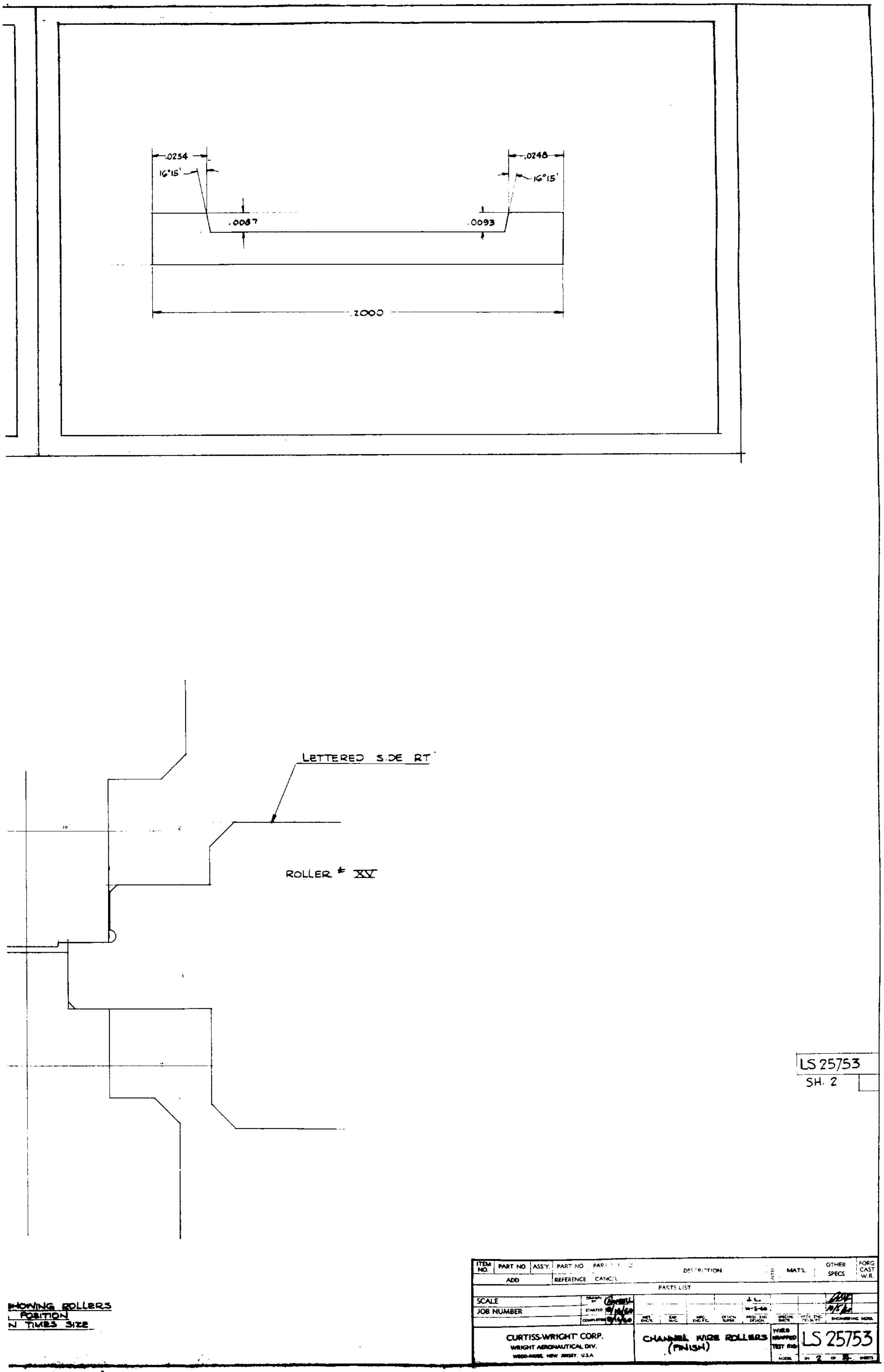
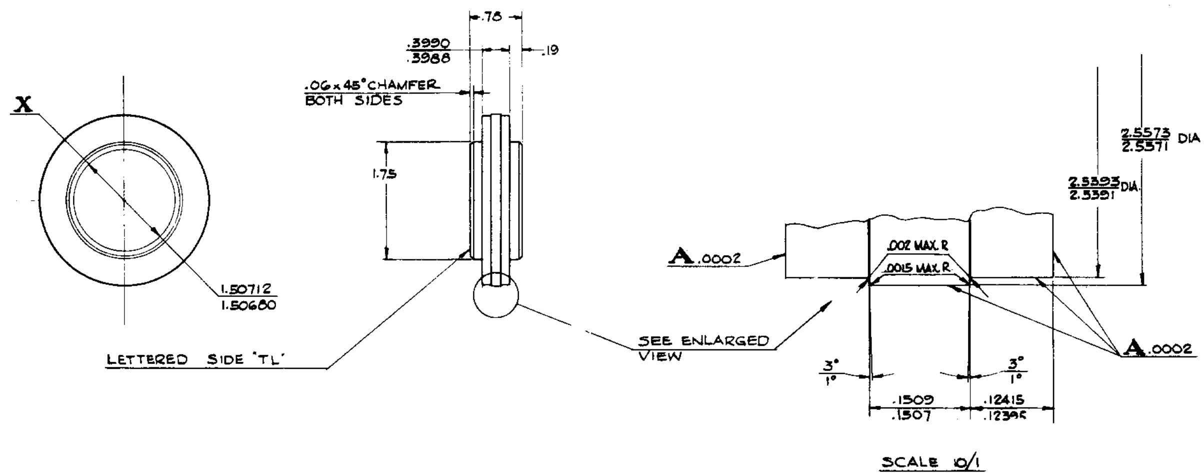
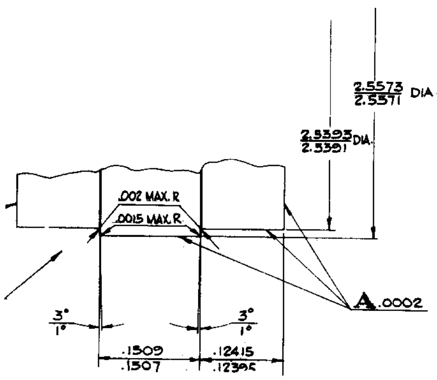
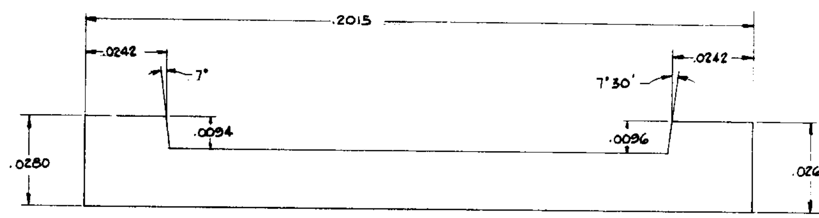

.0254
16°15'
.0248
16°15'
.0087
.0093
.2000
LETTERED SIDE RT
ROLLER # XV
LS 25753
SH. 2
ITEM NO.
PART NO.
ASS'Y.
ADD
REFERENCE
DESCRIPTION
MAT'L.
OTHER SPECS
FORG CAST W.R.
SCALE
JOB NUMBER
CURTISS-WRIGHT CORP.
WRIGHT AERONAUTICAL DIV.
CHANNEL WIRE ROLLERS (FINISH)
LS 25753

Figure 23


X
1.50712
1.50680
LETTERED SIDE 'TL'
.78
.3990
.3988
.19
.06 x 45° CHAMFER
BOTH SIDES
1.75
SEE ENLARGED
VIEW
A .0002
.002 MAX. R
.0015 MAX. R
2.5573
2.5571 DIA
2.5393
2.5391 DIA
A .0002
3°
1°
3°
1°
.1509
.1507
.12415
.12395
SCALE 10/1

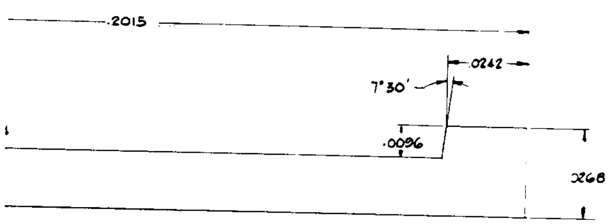


SCALE 10/1



UNLESS OTHERWISE SPECIFIED

CURTISS-WRIGHT CORP
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY, U. S. A.



LS 25753
SH. 3

UNLESS OTHERWISE SPECIFIED
- ALL ANGLES ±2°
- FINISH DIMS ±.010
- FINISH ALL OVER 32

A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED

FOR SIDE ROLLER & BOTTOM ROLLER DETAILS AND SECTION SHOWING ROLLERS IN ROLLING POSITION SEE LS 25753 SH 2

MILITARY SPECIFICATIONS — SPEC NUMBER — DEVIATIONS

DRAWN BY: ARFELL — 11/18/60 — CHECKER — DESIGN SUPVR — PROJECT ENG. DESIGN — PROJ. ENG. DEVEL'PT — PROJ ENG. RESEARCH

STARTED 6/15/60 — COMPL'TD — ENGINEERING — ASST CHIEF ENGINEER — CHIEF ENGINEER

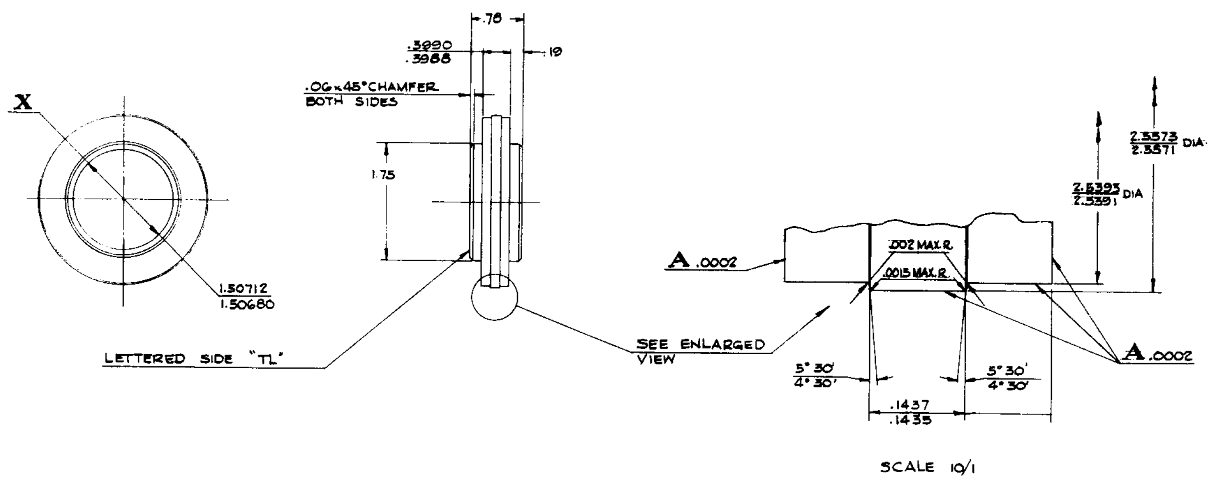
CURTISS-WRIGHT CORP
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY, U. S. A.

CHANNEL WIRE ROLLERS-FINISH

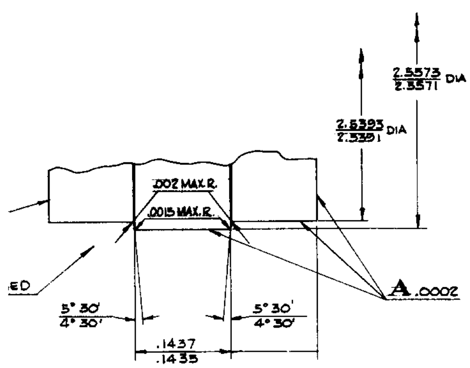
LS25753

MODEL — SH 3 OF 4 SHEETS

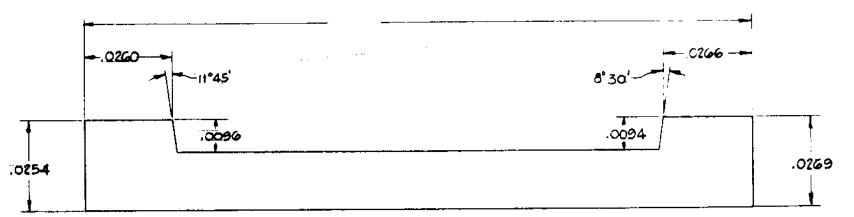
Figure 24



X
1.50712
1.50680
.78
.3990
.3988
.19
.06x45°CHAMFER
BOTH SIDES
1.75
LETTERED SIDE "TL"
SEE ENLARGED VIEW
2.5573
2.5571 DIA
2.5393
2.5391 DIA
A .0002
.002 MAX R.
.0015 MAX R.
A .0002
5° 30'
4° 30'
5° 30'
4° 30'
.1437
.1435
SCALE 10/1

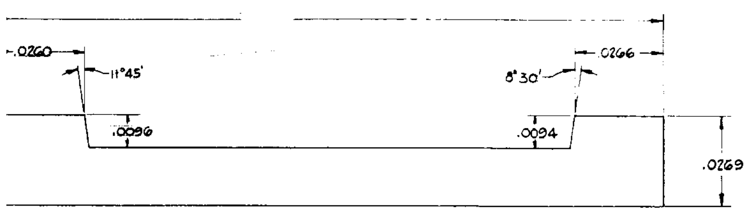


SCALE 10/1



UNLESS OTHERWISE SP

CURTISS-W



LS 25753
SH. 4

UNLESS OTHERWISE SPECIFIED
ALL ANGLES ± 2°
FINISH DIMS ± .010
FINISH ALL OVER 32

A SURFACES CONSTRUCTED AROUND OR AT RIGHT ANGLES TO A COMMON AXIS WHEN PART IS MOUNTED ON SURFACE X MUST BE WITHIN FULL INDICATOR READING SPECIFIED

FOR SIDE ROLLER & BOTTOM ROLLER DETAILS AND SECTION SHOWING ROLLERS IN ROLLING POSITION SEE LS 25753 SH. 2

MILITARY SPECIFICATIONS							
SPEC NUMBERS	DEVIATIONS	DRAWN BY					
		11/17/60	CHECKER	DESIGN SUPER	PROJ. ENG. DESIGN	PROJ. ENG. DEVEL'PT	PROJ. ENG. RESEARCH
		STARTED					
		11/17/60					
		COMPL'TD	ENGINEERING MGRS		M. MECH.	ASST. CHIEF ENGINEER	CHIEF ENGINEER

CURTISS-WRIGHT CORP WRIGHT AERONAUTICAL DIV. WOOD-RIDGE, NEW JERSEY, U. S. A.	CHANNEL WIRE ROLLERS- FINISH	MODEL	LS25753 SH 4 OF 4 SHEETS

Figure 25

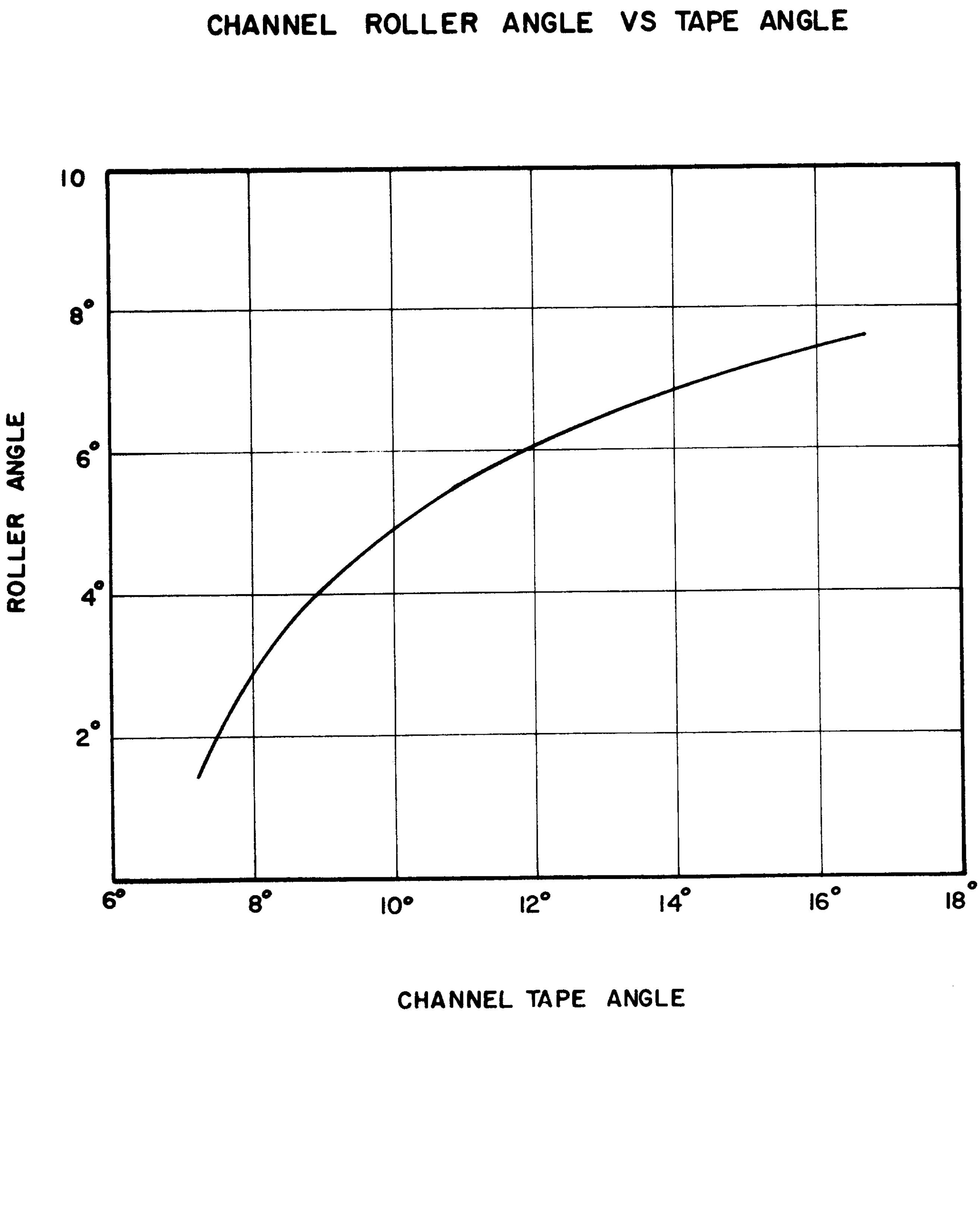

CHANNEL ROLLER ANGLE VS TAPE ANGLE
10
8°
6°
4°
2°
ROLLER ANGLE
6°
8°
10°
12°
14°
16°
18°
CHANNEL TAPE ANGLE

Figure 26

5.0 METALLURGY

5.0 METALLURGY

5.1 Work Statement

Metallurgical work carried out under the present contract includes tape manufacture, development of measuring techniques, measurement of interference fit, development of heat treatment, determination of frictional coefficients, evaluation of liner and bonding methods and a limited number of low temperature tensile tests.

5.2 Starting Material

Commercial B120VCA titanium alloy weld wire produced by centerless grinding and drawing was procured in the mill annealed condition. Two sizes, .154" and .123" were evaluated resulting in the final selection of .123" nominal gage for both shapes. The fabrication of lengths in excess of 100 ft., though successful in some heats, resulted in cracking and rupture in the case of the most recently purchased material. Poor wire surface in "as received" material was observed to contribute to this problem. Superficial pickling, either acid or basic, found effective in improving surface condition was not always found to alleviate the problem. Other possible causes include hydrogen embrittlement, surface contamination, and variances in chemical composition. In order to insure quality and uniformity in future purchases a specification for B120VCA material in the form of coils of wire was prepared. This specification is reproduced in detail in Appendix III.

5.3 Rolling Techniques

5.3.1 Round Wire Breakdown

5.3.1.1 "I" Beam

The round wire discussed in Section 5.2 is cold reduced to a rectangular shape prior to further reduction in the Turks head mill. Originally, a Universal Turks head was used to produce all rectangular shapes. This procedure was abandoned in favor of a more rapid procedure which utilizes power driven rolls. The current breakdown is carried out in a groove mill and a flat mill, and is as follows:

5.3.1.1 "I" Beam (Continued)

Pass No.	Mill	Thickness of Rectangle	Width of Rectangle
1	Groove	.118	.118
2	Groove	.108	.108
3	Groove	.100	.100
4	Flat	.092	.108
5	Flat	.084	.116
6	Flat	.076	.124
7	Flat	.068	.132
8	Flat	.062	.140

5.3.1.2 Channel

The breakdown of round wire into rectangular cross-sections for the channel tape is more complicated since the amount of spread (.121" Dia. to .2165") is much greater. This procedure also requires the use of a groove mill and a flat mill, and is as follows:

Pass No.	Mill	Thickness Rectangle	Width of Rectangle
1	Groove	0.1050	0.1320
2	Groove	0.0990	0.1352
3	Groove	0.0950	0.1395
4	Groove	0.0900	0.1425
5	Groove	0.0855	0.1466
6	Flat	0.0810	0.1510
7	Flat	0.0760	0.1570

5.3.1.2 Channel (Continued)

Pass No.	Mill	Thickness of Rectangle	Width of Rectangle
8	Flat	0.0720	0.1615
9	Flat	0.0590	0.1760
10	Flat	0.0540	0.1816
11	Flat	0.0494	0.1887
12	Flat	0.0443	0.1950
13	Flat	0.0396	0.2030
14	Flat	0.0350	0.2100
15	Flat	0.0310	0.2165

The problem of reducing round wire to the rectangular starting shapes necessary for Turks heading was further complicated by the necessity of avoiding the use of oxide coatings which normally serve as lubricants. Oxide coatings were found to result in embrittlement in the subsequent Turks heading operation.

5.3.2 Turks Heading of Rectangular Wire

Initially, two procedures of cold reducing rectangular B120VCA titanium wire were considered. Use of power driven rolls in a "shell mill" was believed to offer the advantages of spreading rather than elongating the material and allowing heavier reductions per pass because no extremely heavy pull was needed. It was, however, found that the accuracy of the shell mill was not sufficient to maintain the critical internal shapes, particularly the angles. Heavy passes resulted in cracking of the wire. Intermediate annealing was discarded since it lowered the attainable strength of the final product. Emphasis was, therefore, placed on the Turks heading method.

5.3.2 Turks Heading of Rectangular Wire (Continued)

This method, utilizing idling rolls through which wire is drawn, was believed to offer greater flexibility and sensitivity of adjustment, hence, better accuracy. The Turks head mill is an apparatus comprising four rolls which are housed at a 90^o angle to one another. Depending on the model, the rolls may be adjusted independently or in pairs. The rolls can move in one direction only, i.e., up or down. A third available model, the "combination" Turks head incorporates the above and in addition, provides means for lateral adjustment.

It was initially thought that by limiting reductions in each pass to a small percentage, large total reductions in area could be obtained. In addition, it appeared advisable to employ one or more intermediate anneals.

Numerous samples were produced by thus "babying" the material, but with varying degrees of success. Intermediate anneals were found to reduce the final attainable strength. It was found that optimum aging response was obtained when the cold worked material after the final pass exhibited a tensile yield strength of 210,000 psi.

Patterning the shaping steps for either the "I" beam or channel shapes after steel mill practice proved unrewarding since the flow characteristics of titanium are totally different. The forming rolls, each taking relatively heavy reductions, were arrived at by trial and error. An extremely heavy finishing pass was necessary in order to avoid steps in the internal walls.

Though the finished dimensions obtained by the heavy reduction method proved superior to those produced by the previously used light reduction method, a number of new problems were introduced. These problems included cracking of the rolls as well as excessive wear of the roll arbors. Changes in the roll materials, heat treatment and chrome plating of arbors, though successful to a limited extent, were not considered satisfactory for rolling long lengths. Consequently, a larger Turks head mill (No. 3TH) was purchased. This resulted in lower Hertz stresses in the rolls and lower bearing stresses in the arbors. A Kerosene-water mixture was used as a lubricant.

5.3.2 Turks Heading of Rectangular Wire (Continued)

The techniques developed for the processing of tape in the small mill were found applicable in the larger mill, resulting in the successful production of the desired shape (Figure 3). Roll design, spring back calculations and modifications of rolls are reported in another portion of the present report (Section 4).

5.3.2.1 "I" Beam

Using the procedure outlined in the above section, the best "I" beam shape was produced in two (2) heavy passes. The first pass reduced the webb to 0.0416 and the overall length to .1370. The final pass reduced the webb to .0395 and the length to 0.134.

5.3.2.2 Channel

The final channel cross-section being smaller, but wider, than the "I" beam required somewhat smaller reductions. The following is the proceudre employed for the manufacture of the channel type.

Pass No.	Channel Webb Thickness	Channel Width
1	.029	.2045
2	.027	.2043
3	.025	.2042
4	.023	.2041
5	.021	.2041
6	.0195	.2040
7	.0185	.2035
8	.0175	.2030
9	.0165	.2000
10	.0155	.2000

Figure 27 illustrates the major steps in the fabrication of the channel shape. As illustrated, shapes K through O contain ridges at the base of the channel which are used to force material to flow upward.

Figures 28 and 29 illustrate both cross sections in the etched and unetched condition. As may be observed from Figure 29, flow lines follow the internal corners indicating favorable flow with respect to the interference fit and final pressure vessel requirements.

5.4 Evaluation of Measuring Techniques

The measurement of both shapes has presented a serious problem due to the close tolerance requirement imposed. An investigation of several measuring methods was carried out. These include measurement by means of a comparator, projection by means of a metallograph, micrometer measurement of external dimensions, measurement of a calcium sulfate mold and use of toolmakers' microscopes and air gages.

The projection of both shapes by means of a comparator resulted in readings differing by as much as .0025 from outside dimensions as measured by a micrometer. This was primarily due to distortion in the tape produced by cutting. Glancing of the comparator beam from a flexed portion of the tape also proved inaccurate because of distortion.

The above attempt also showed that any twist or bend could produce erroneous results. This imposed the requirement that measurement must be made in a perpendicular plane. This was accomplished by copper plating (non-adhering) the tape to a thickness of approximately 0.005 inch. The tape was then placed in special metallographic clamps as illustrated in Figure 30. The specimen was then polished metallographically and photographed at 50X. The photographs were then measured.

Comparison of the results obtained using the above procedure with micrometer measurements revealed a difference much less than those obtained with a comparator. However, this difference (.0005 - .0001 inch) was still considered too great. It was decided that the metallographic method be used to measure only dimensions which could not be measured with a micrometer.

In an effort to obtain greater accuracy a fourth method was attempted whereby a small mold was clamped onto a portion of the tape, and filled with $CaSO_4 \cdot 1/2\ H_2O$ solution. This solution was allowed to set for 2 hours. The impression thus produced was then projected on a comparator and measured. These measurements also did not agree (0.001 inch larger) with micrometer measurements.

External comparators, toolmakers' microscopes, and air gages, in combination, were tried next. A comparison of the dimensions obtained by this method versus those obtained by metallographic and micrometer methods is as follows:

5.4 Evaluation of Measuring Techniques (Continued)

	Width	Height	Groove Depth	$\angle$ 1	$\angle$ 2	$\angle$ 3	$\angle$ 4
"I" Beam							
Non-Metallographic	.1378	.060	.0093			20°	15°
Metallographic	.1343	.0586	.0100	7°30'	6°	16°	15°30'
Channel							
Non-Metallographic	.2025	.0265	.0095	9°	14°		
Metallographic	.2015	.0268	.0095	7°	7°30'		

Note:

$\angle$ 1 = top left side
$\angle$ 2 = top right side
$\angle$ 3 = bottom left side
$\angle$ 4 = bottom right side

The above comparisons show that there is a large discrepancy between the two methods. More significant however, is the fact that the non-metallographic measurements do not agree with succeeding attempts to measure the same tape.

5.5 Interference Fit

It was desired to obtain a measurement of the forces involved to produce an interference fit between the "I" beam and the channel, even though the "I" beam was out of tolerance initially. The test was accomplished in the following manner: Two one inch lengths of channel were butted against each other and the "I" beam placed over the flats. Two more channels were then added to complete the top layer. The assembly was then hydraulically pressed together in a flat position. The gauge pressure was increased from 0 to 3000 psi, to 5000 psi, to 7000 psi and finally to 10,000 psi. At each pressure reading the tapes were polished, etched and photographed. Pressure was maintained on the sample at all times.

This procedure determined the force required to produce an interference fit.

5.5 Interference Fit (Continued)

A determination of the force needed to achieve an interference fit is carried out as part of evaluation of each tape lot produced. Figure 31 shows the results of pressing together the tapes shown in Figure 32. The load was applied in the center of the "I" beam. It may be noted that the center of the "I" beam has deflected before one side has had a chance to seat. This caused a cocking effect resulting in an unsatisfactory interference fit. Another set of channels and an "I" beam were pressed together with the load applied to the "I" beam flanges. The result is illustrated in Figure 33. This loading method eliminated some of the bowing and resulted in better seating of the sides. The lack of good fit is due to the undersized width of the "I" beam groove. Despite this the tapes stayed locked after the load was released.

In order to determine the amount of interference fit from the standpoint of assembled dimensions and force needed for separation, an experiment was carried out whereby the "I" beam and channel tapes shown in Figures 21 and 25 were pressed together (2 layers) and the total thickness measured (from inside of "I" beam to outside of channel) as a function of applied load. The results are given in Figure 34. It can be seen that a 2400 psi force was necessary to initiate a permanent interference fit and a 5000 psi force was necessary to seat the "I" beam on the channel. Figure 36 shows a 3 layer assembly pressed together under a 5000 psi force. Though some separation is still believed to be present, the illustration exaggerates this due to rounding of edges during polishing. This fact is confirmed by observation of strain markings adjacent to "gaps" when the assembly was subjected to higher compressive loads.

In order to estimate the force needed to overcome the interference fit, the fully seated sample was attached to small tensile machine grips by means of wires. Despite non-concentric loading, a load of 14 pounds was required to fail the 1" long assembly. Reseating of the specimen and repetition of the test resulted in a failure load of 11 lbs. A third test of the same specimen yielded a failure load of 6 pounds.

The values obtained are considered sufficient to prevent unwrapping (during vessel assembly) of a partially wrapped layer upon removal of the restraining forces imposed by the wrapping mechanism and drag break. This was verified during trial wrapping of a dummy arbor.

5.6 Tensile Testing Apparatus

All attempts to test both "I" beam and channel shaped tapes in tension have failed to give reproducible values. This is due to the fact that the tapes broke at the grips. Consequently, a rig has been designed whereby the tape is wound on a drum at each end. These drums, in turn, have plates welded to them which are held by the grips. The frictional force created by the wound tape is sufficient to prevent slippage. This apparatus has been constructed and is shown in Figure 36 (LS 25806).

5.7 Heat Treatment

The heat treat proceudre was designed to produce optimum properties in both channel and "I" beam tape, keeping in mind the goal of a 250,000 psi yield strength with 4 percent ductility.

The specimens to be heat treated were first degreased and then capsulated in vacuo. Heat treatment was carried out in a furnace of constant heat zone (± 5°F) for various times ranging from 5 hours to 38 hours at a given temperature. This procedure was repeated at several temperatures until the time and temperature to produce maximum properties was found. The results are presented in the following sections.

5.7.1 Channel Heat Treatment

The results of aging channel tape are presented in Table I and Figure 37. The maximum yield strength was obtained after aging at 700°F for 12.5 hours. The yield strength produced by this treatment was approximately 278 ksi while the ultimate strength was 280 ksi. The elongation was 1.5 percent in an 1" gage length. This heat treatment results in approximately the same properties as the "I" beam heat treatment.

5.7.2 "I" Beam Heat Treatment

The results of aging "I" beam tape are given in Table II and are presented in Figure 38. The maximum yield strength was obtained after aging at 750°F for 25 hours. The ultimate tensile strength produced by this treatment was approximately 279,000 psi and the yield strength was 272,000 psi. The elongation was 1.5 percent (1" gage length).

5.7.3 Metallographic and Hardness Study

The aging response of the channel tape as a function of percent reduction in area and hardness was investigated. This was accomplished by aging samples, having the cross-sections shown in Figure 27 at 750°F for 20 and 46 hours in a vacuo. The resulting microstructures are presented in Figure 39. It may be seen that these microstructures indicate behavior in a normal fashion with evidence of aging taking place at the first Turks head breakdown pass on (a) and (b). The presence of a spheroidal precipitate (probably $TiCr_2$) shown in Figure 39 (c) is indicative of overaging.

A Vickers hardness survey using a 5 kilogram load was taken across the above specimens. The results are shown in Figure 41. The curves indicate an increase in hardness with increasing reductions. The 47 hour-aged hardness is less than the hardness obtained with the 20 hour treatment.

5.8 Elimination of Twist* and Bow **

Twisting and bowing of tapes was found to cause difficulty during the wrapping operation. Twisting resulted in cocking, particularly in the case of the "I" beam, resulting in loss of interference fit. Bowing resulted in a "pre-set" helix causing difficulty during stacking, particularly in the case of the first channel layer.

Both problems are associated with the use of the bull block which supplies the force necessary to draw the tape through the Turks head. In order to eliminate bowing as well as twisting, a specially designed arrangement is being substituted for the presently used bull block.

5.9 Coefficient of Friction

The design of both channel and "I" beam shapes assumed a coefficient of static friction of 0.3-0.5. An investigation to determine the actual value was performed in the following manner:

* Twist - Rotation of cross-section about tape axis.
** Bow - Bending of the tape axis parallel to the plane of the web.

5.9 Coefficient of Friction (Continued)

Two titanium channel tapes were mounted back-to-back and clamped with a predetermined load (Figure 41). The channels were then pulled in opposite directions and the load to initiate slippage noted. This experiment was repeated with different clamping loads and the corresponding slippage loads recorded. The results are tabulated in Table III.

An increase in the coefficient of static friction from .270 to .348 as a result of heat treating was observed. Analysis shows the interlock to be effective only when the condition $\tan \theta < \mu$ is satisfied, where θ is the interference fit angle, and μ the coefficient of static friction. Figure 42 shows the derived relationship between the tape angle and coefficient of friction.

5.10 Evaluation of Bonding Methods

In accordance with design requirements, it is essential that the tape be bonded to the adapters. The possibilities considered include brazing, soldering, ultrasonic welding, and the use of resins.

The goal was to obtain a tensile shear strength of 4,500 psi with 0.001" strain.

Brazing was not attempted since the temperatures involved are usually above 1000°F which is in excess of the upper limit of the aging temperature. Low temperature brazing or soldering and ultrasonic welding were found unsatisfactory. Epoxy resins appeared attractive since they are either room temperature curing or cure at slightly elevated temperatures. An evaluation was carried out wherein a piece of steel large enought to contain a piece of B120VCA channel tape was zirconite blasted and degreased. The titanium tape was cleaned in 3 parts HF-30 parts HNO_3 solution for one minute and washed in water. The resin was applied to both parts which were then allowed to come in contact with each other. The specimens were pulled in uniaxial tension using self-aligning grips. A deflectometer was used to measure the cross-head movement. B120VCA channel tape was previously tested and stress-strain curves determined. At given loads a corresponding strain of the tape was subtracted from the total deflection and stress-strain curves for the resins were then drawn. From these curves a modulus of elasticity for each resin was calculated.

5.10 Evaluation of Bonding Methods (Continued)

Tests showed that the resins all had modulli of elasticity in the neighborhood of 10,000 to 25,000. These results are tabulated in Table IV and are illustrated in Figure 43. It was found that Maraset (Marbellette Corporation) had the highest strength and elastic modulus while Bondmaster (Rubber and Asbestos Corporation) was next. Eastman 910 and Goodyear Plibond did not adhere. Since a value of 4,500 psi was required at a 0.001" strain, the material would require a modulus of elasticity of 4.5×10^6. This could not be attained in resins.

5.11 Vessel Liner Evaluation

A test was carried out to determine the adherence and elastic properties of Teflon as a vessel liner. The vessel is so designed that a sharp angle exists where the first tape layer leaves the adapter. For testing purposes two (2) pieces of metal (titanium and steel) were joined together as shown in Figure 44. Teflon was then sprayed over the joint and the metal pieces pulled in tension with a 4500 pound force.

The results of this test showed that Teflon could not be relied upon to fill this corner and provide a leak-tight joint. In view of this, a modified Teflon and vinyl were tried. The results of this evaluation indicated that the modified Teflon flaked when subjected to tensile loading. However, the vinyl coating withstood the required strain (4500 lb. load) without any noticeable cracking or flaking.

5.12 Cryogenic Properties of B120VCA Ti

The results of limited low temperature tensile tests are presented in Figure 45 and shown in Figure 46.

The room temperature smooth sheet specimens had a gage length of 2-1/2" and a width of .400 ± .005". The low temperature smooth sheet specimens were the same except that the specimen width was .250".

The notched specimens were the same as the room temperature smooth specimens, except for a notch with a root radius of 0.010 ± .001", an included angle of 45° and the minimum width was .270 ± .003".

It can be seen from these results that this alloy is not reliable for cryogenic vessels, the notched-to-unnotched tensile strength ratios being 0.34 at -320°F.

Tests run on a second heat and a 0.050" gage thickness produced the same results.

CHANNEL BREAKDOWN

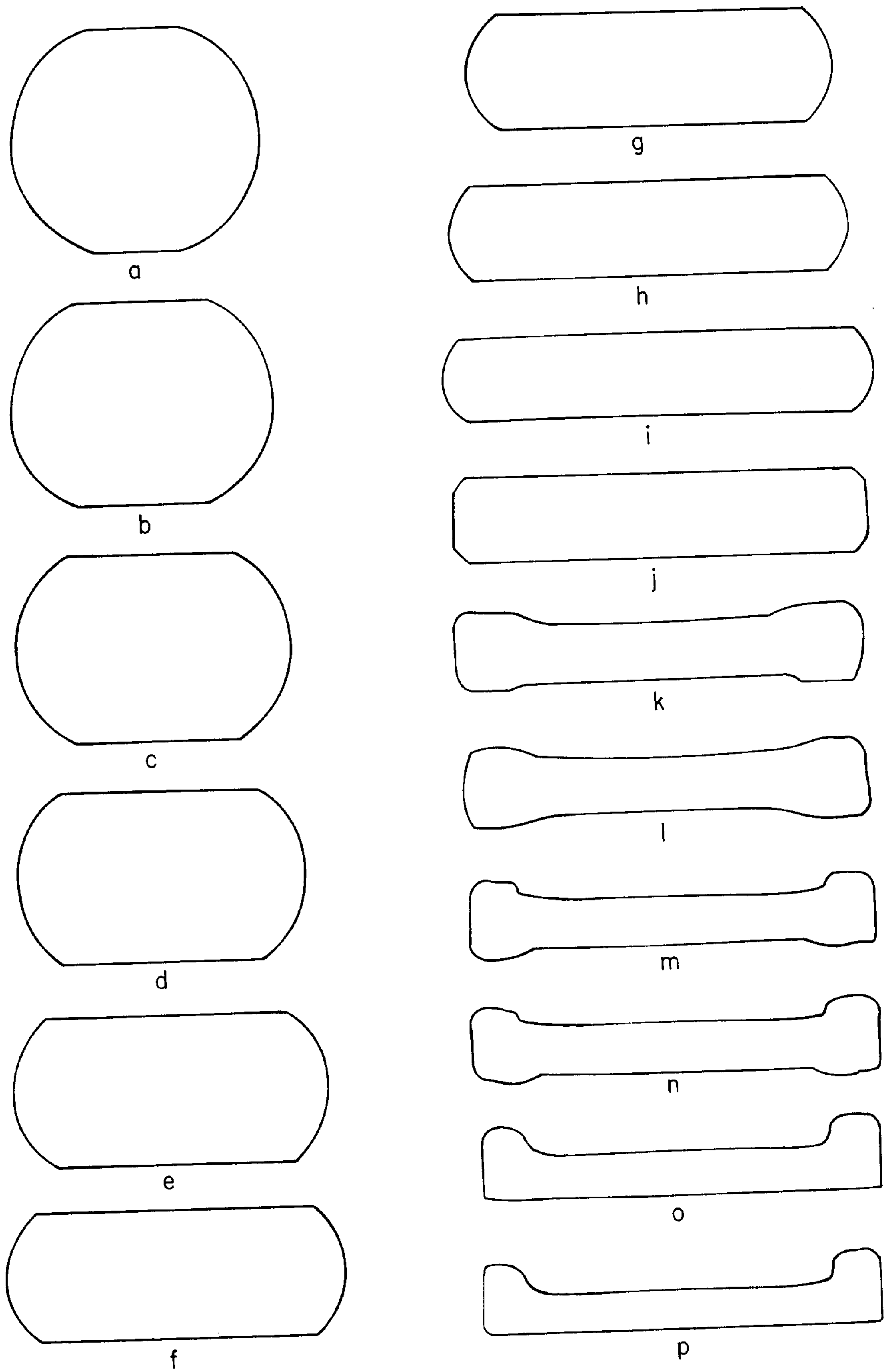
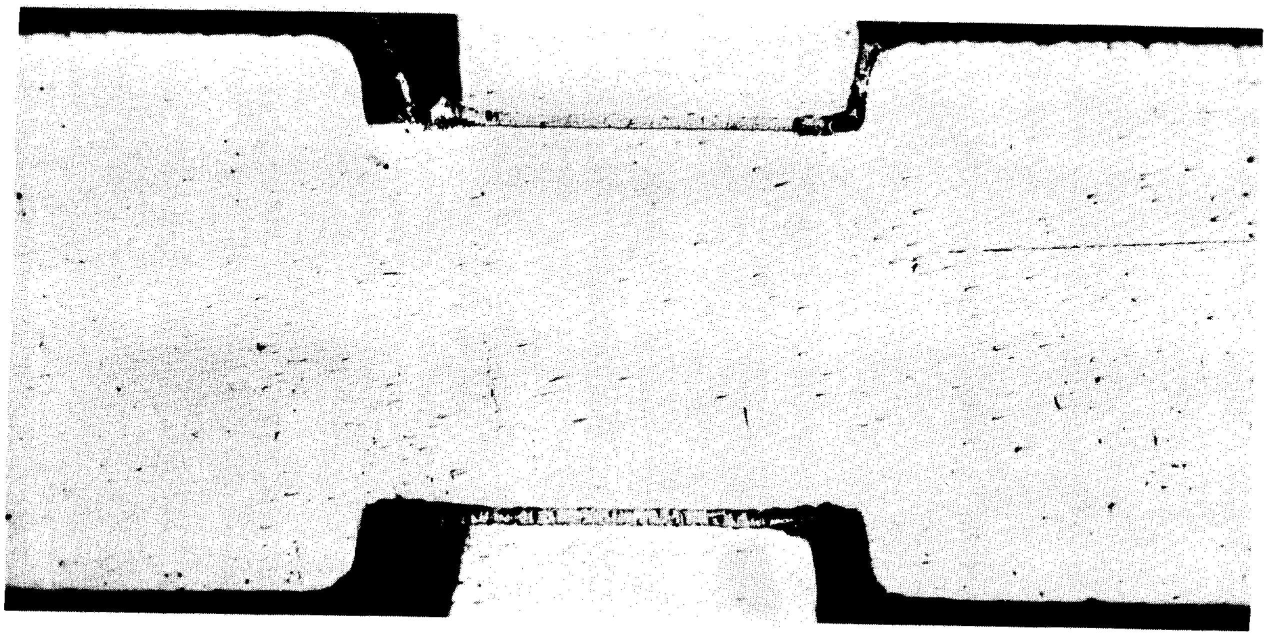
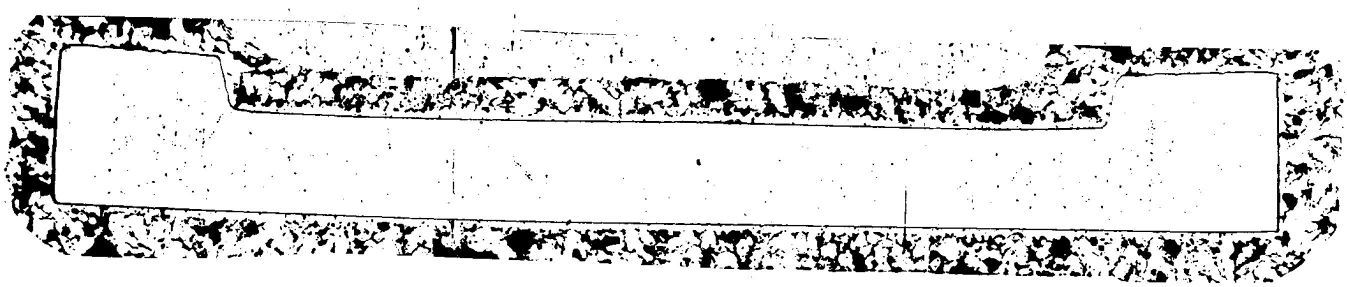


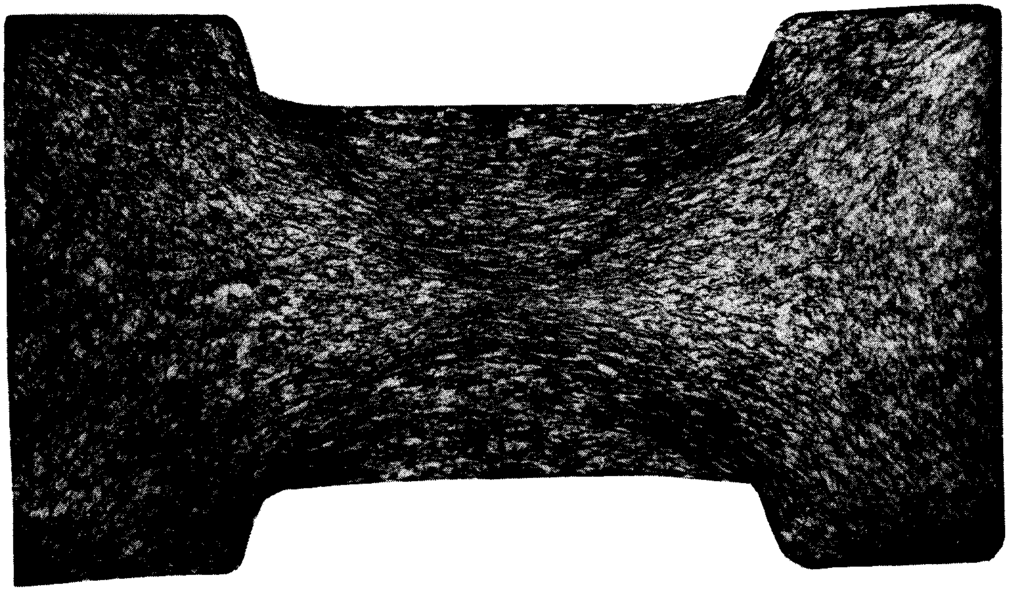
Figure 27

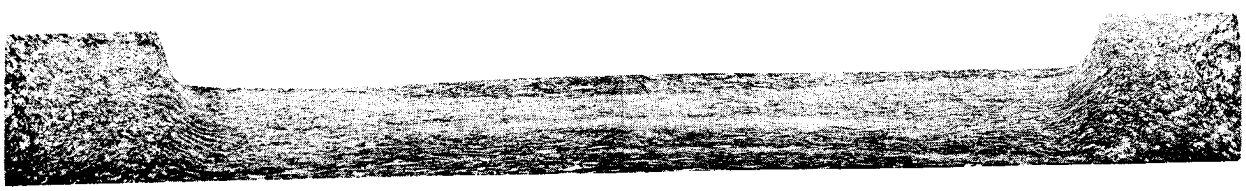




Specimens Mounted for Measurement

Figure 28

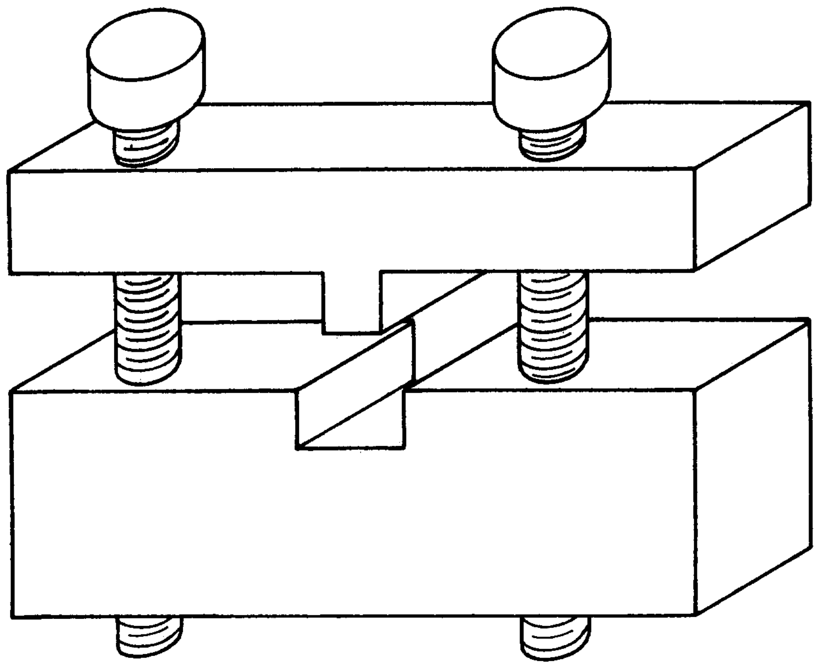




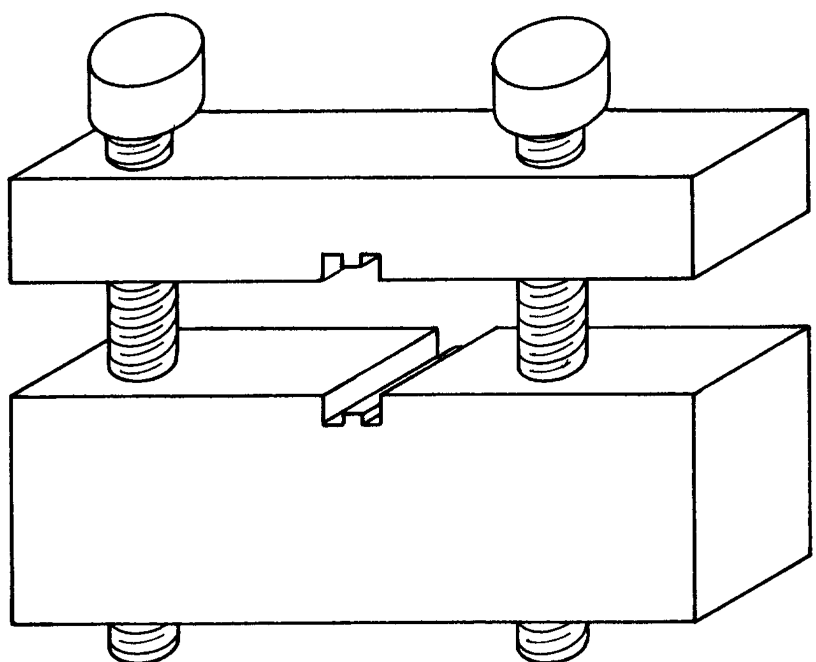
"I"-Beam and Channel Flow Lines

Figure 29

SCHEMATIC ILLUSTRATION OF METALLOGRAPHIC CLAMPS

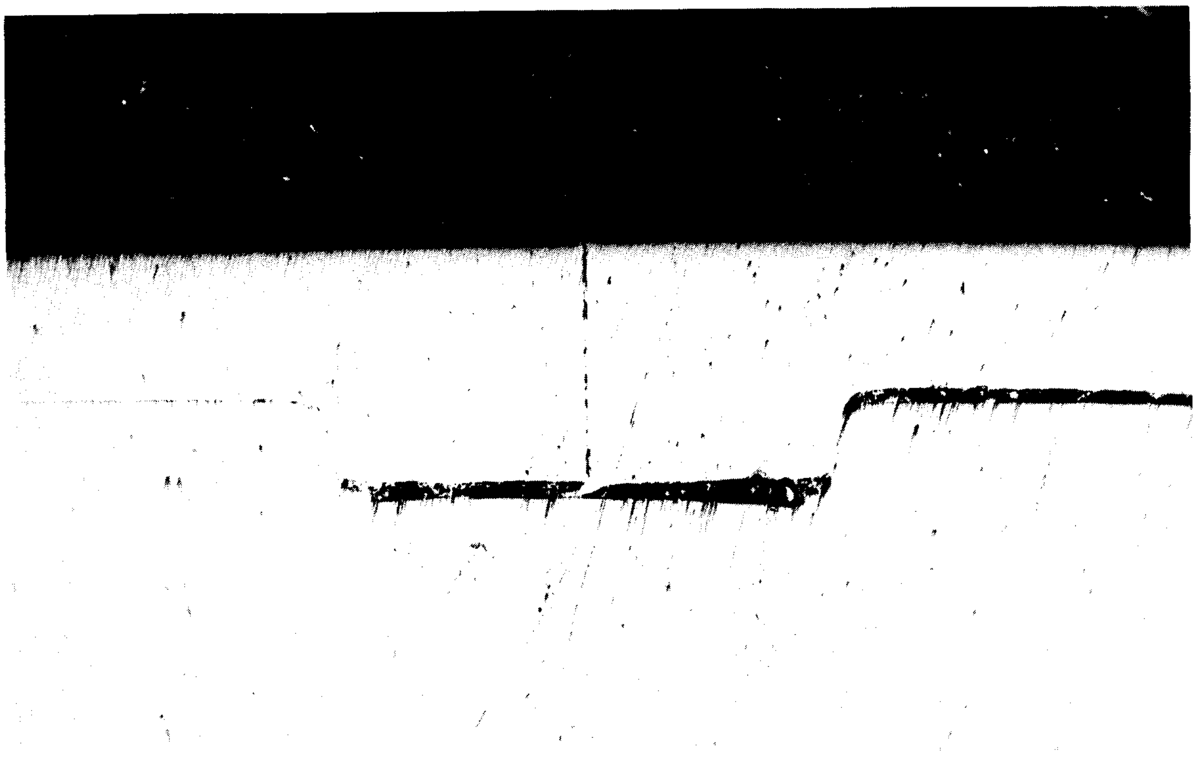


CHANNEL



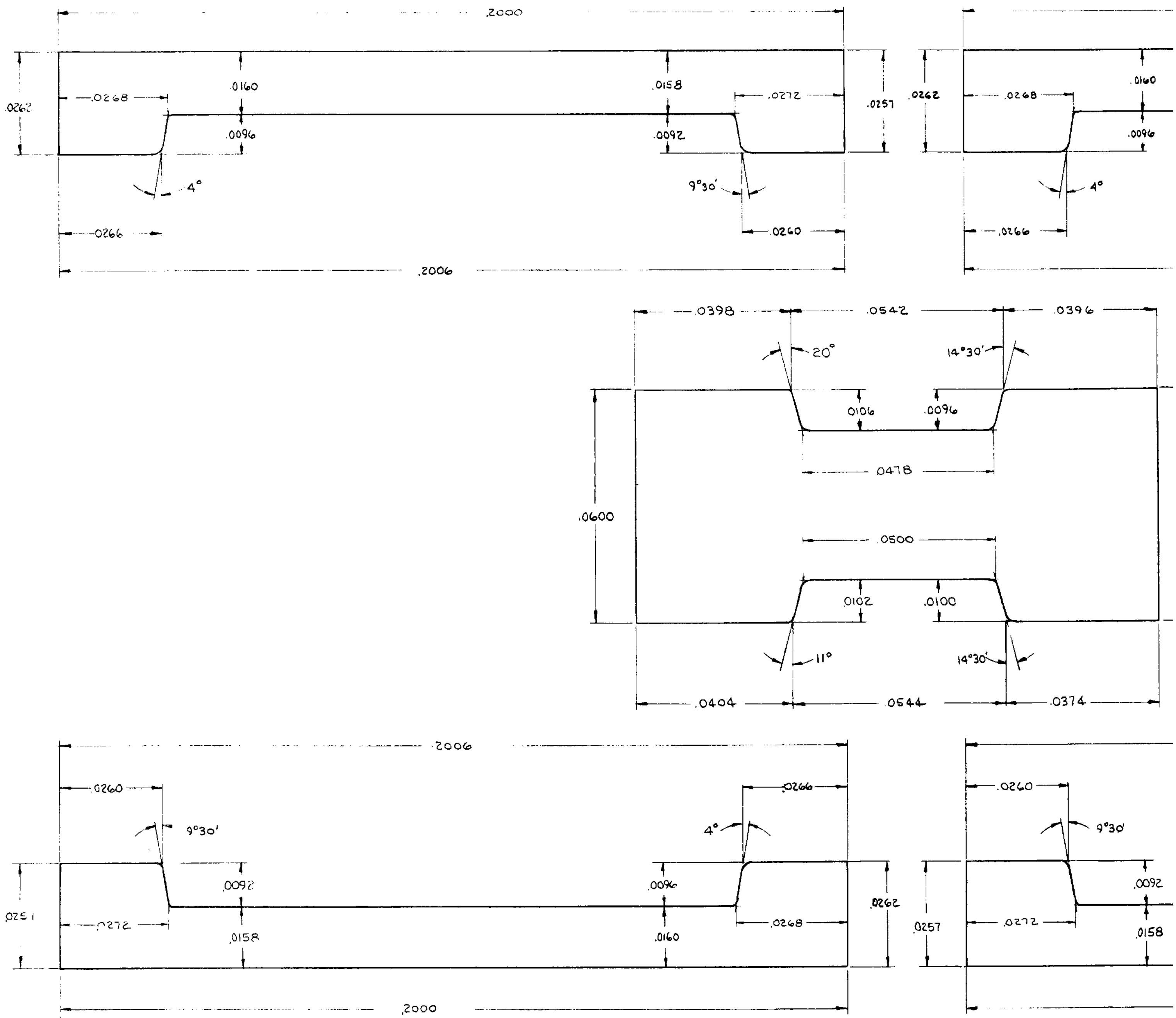
"I" BEAM

Figure 30

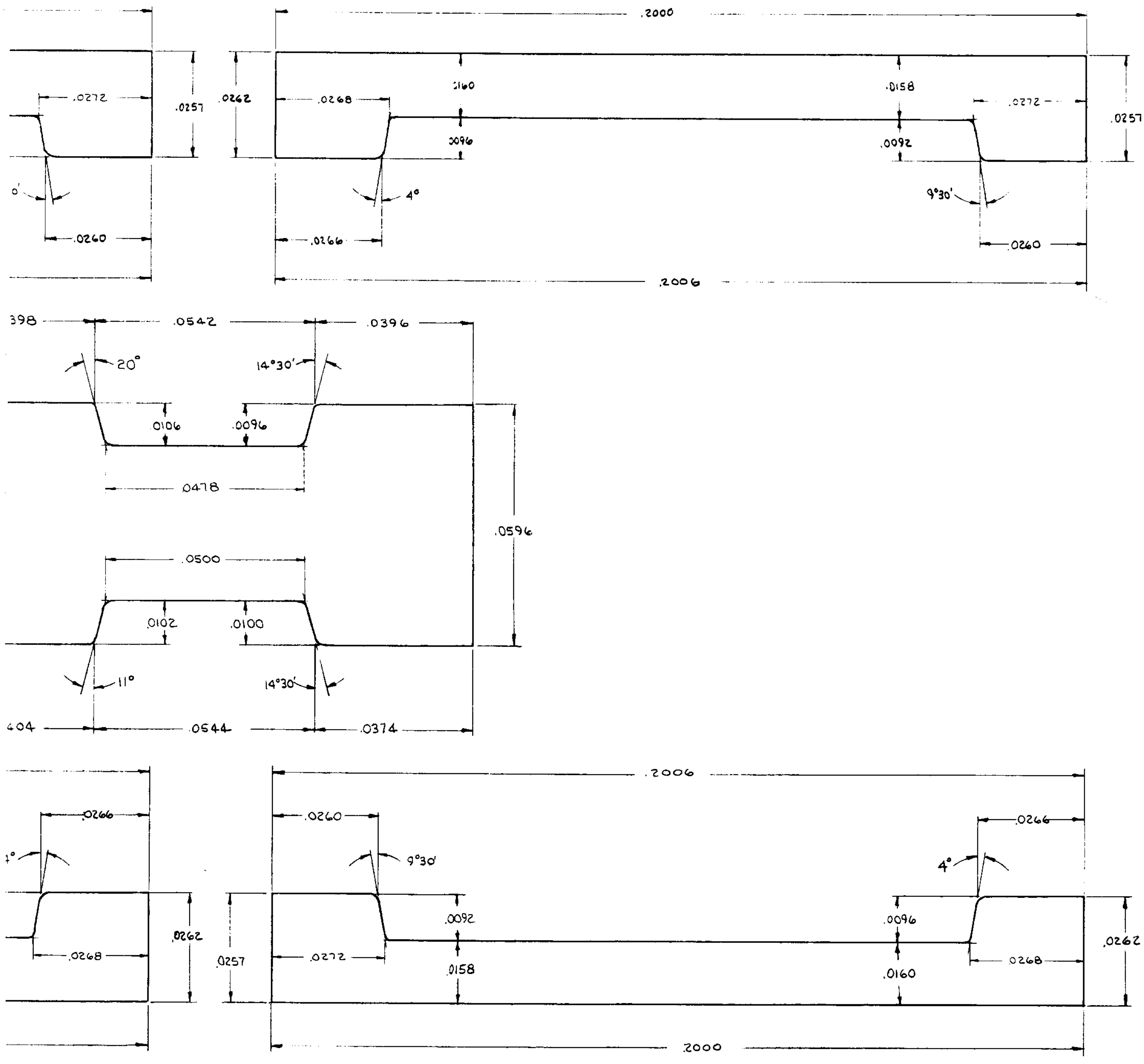


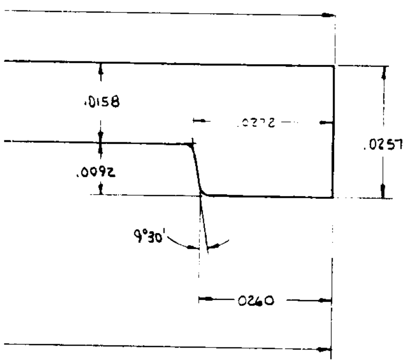
"I"-Beam - Channel - Pressed

Figure 31



.2000
.0262
.0268
.0160
.0096
.0158
.0092
.0272
.0257
4°
9°30'
.0266
.0260
.2006
.0398
.0542
.0396
20°
14°30'
.0106
.0096
.0478
.0600
.0500
.0102
.0100
11°
14°30'
.0404
.0544
.0374


.2000
.0272
.0257
.0262
.0268
.160
.0158
.0096
.0092
.0272
.0257
4°
9°30'
.0260
.0266
.0260
.2006
398
.0542
.0396
20°
14°30'
.0106
.0096
.0478
.0596
.0500
.0102
.0100
11°
14°30'
404
.0544
.0374
.2006
.0266
.0260
.0266
9°30'
4°
.0262
.0092
.0096
.0262
.0268
.0257
.0272
.0158
.0160
.0268
2000



DATE -

DUMBBELL LOAD	LBS.
CHANNEL LOAD	LBS.
YIELD STRENGTH	P.S.I.

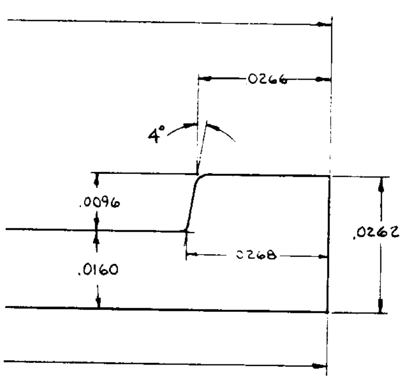
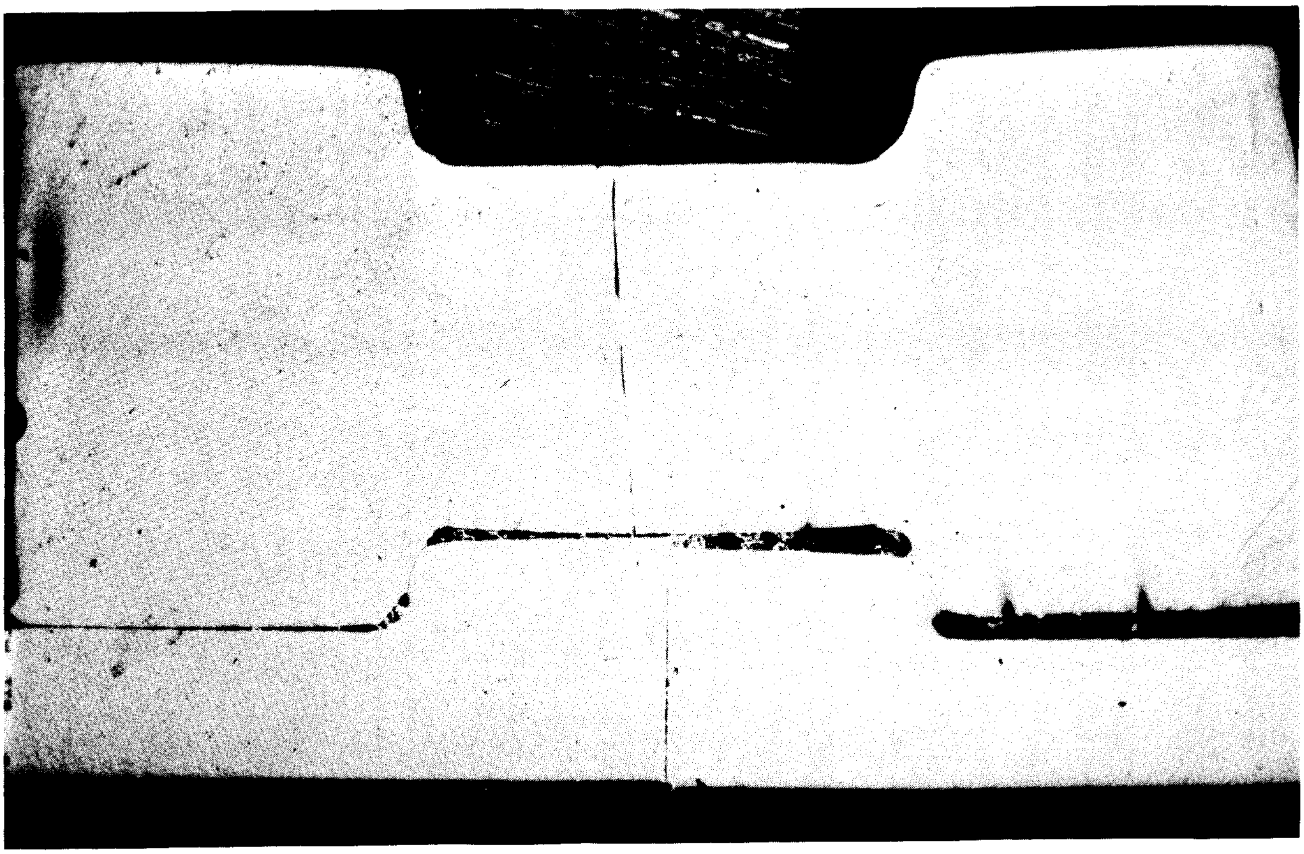


Figure 32



"I"-Beam - Channel - Pressed

Figure 33

DEGREE OF INTERFERENCE FIT

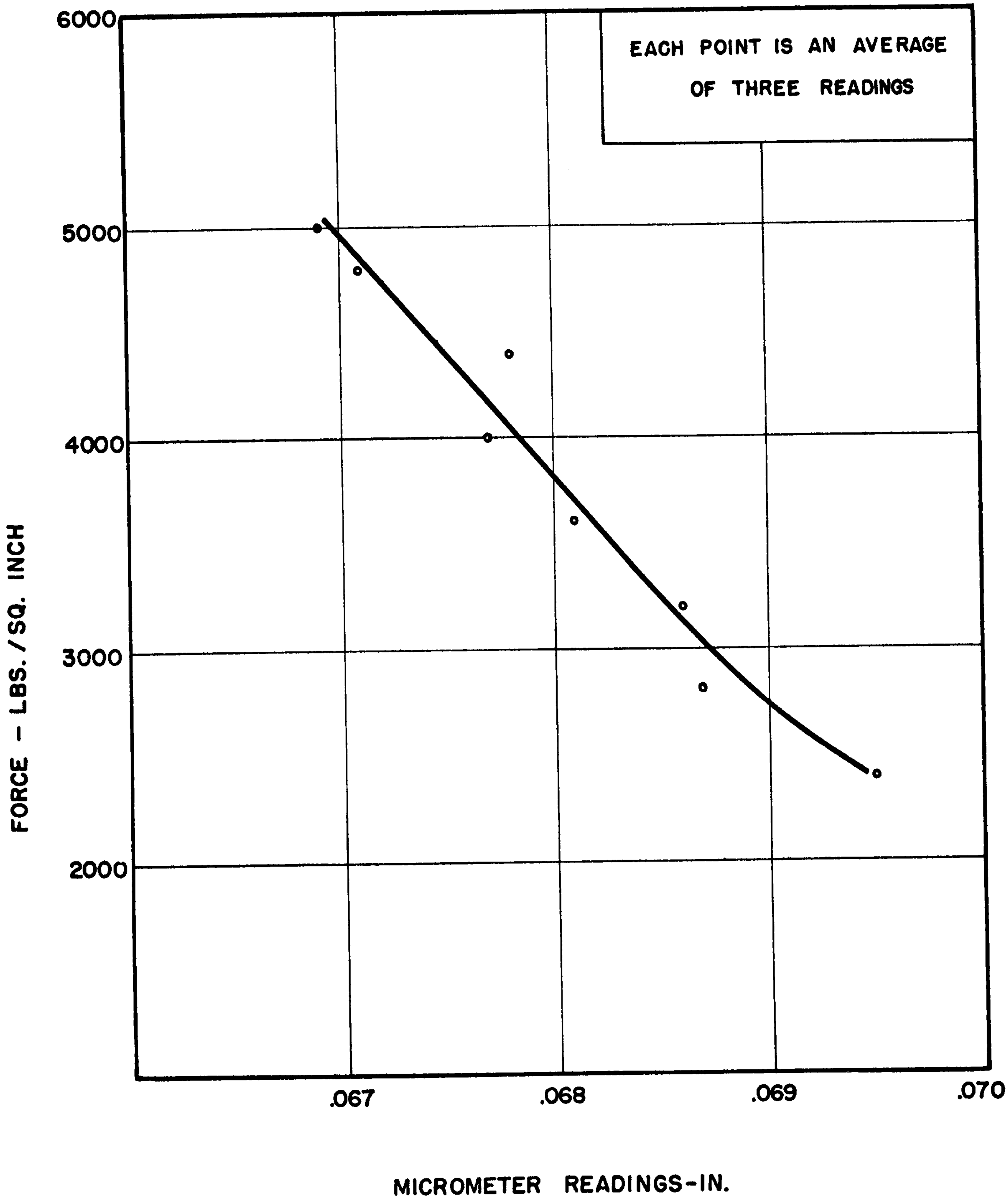
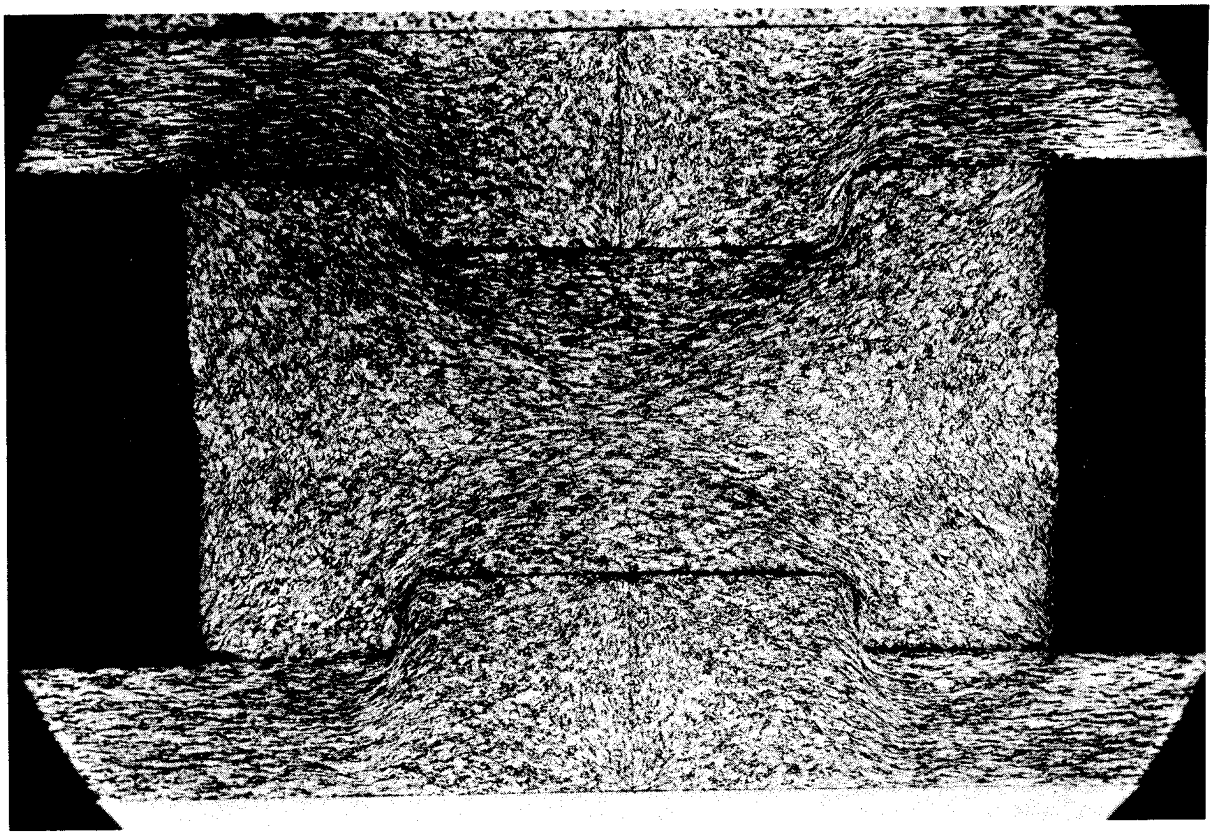
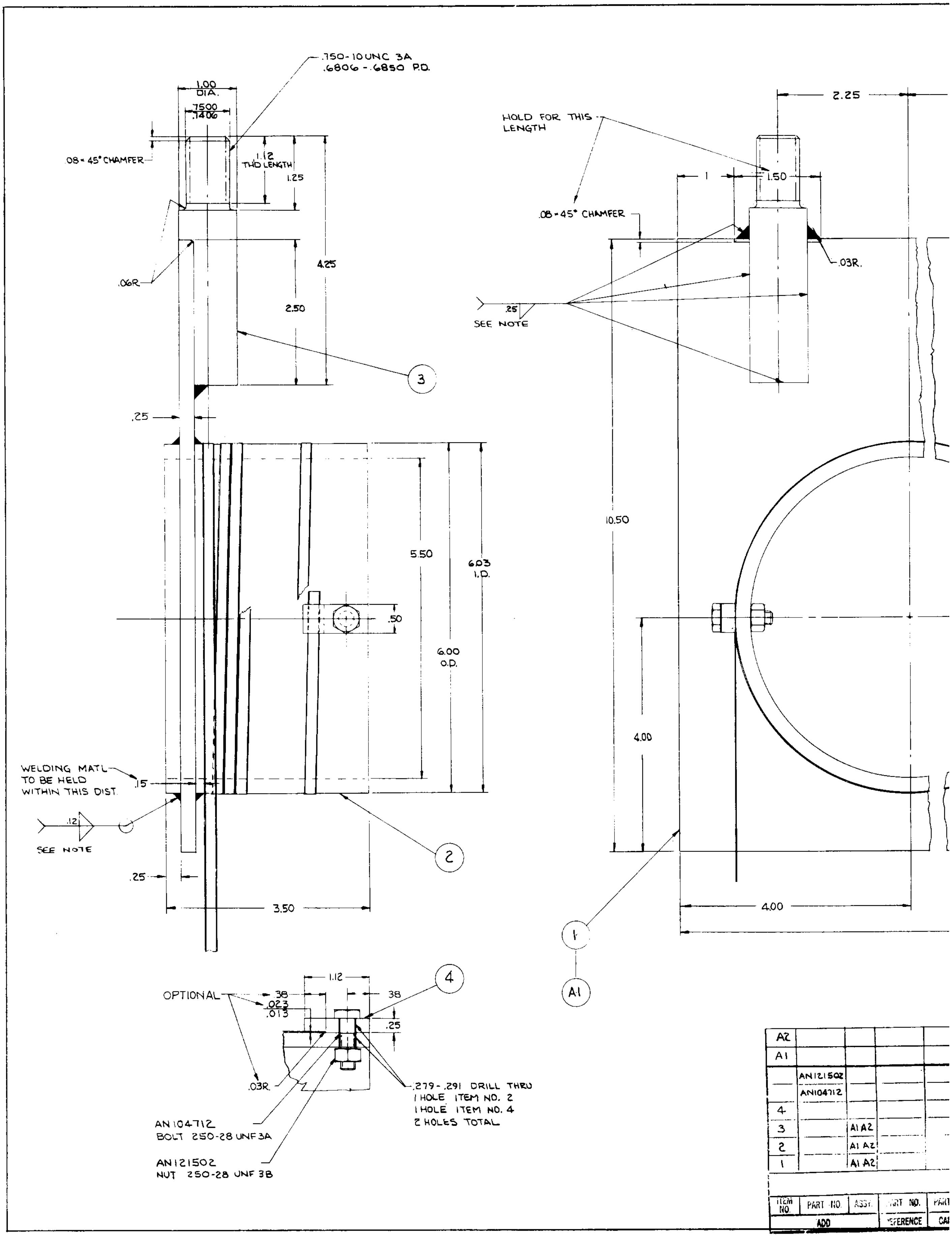


Figure 34

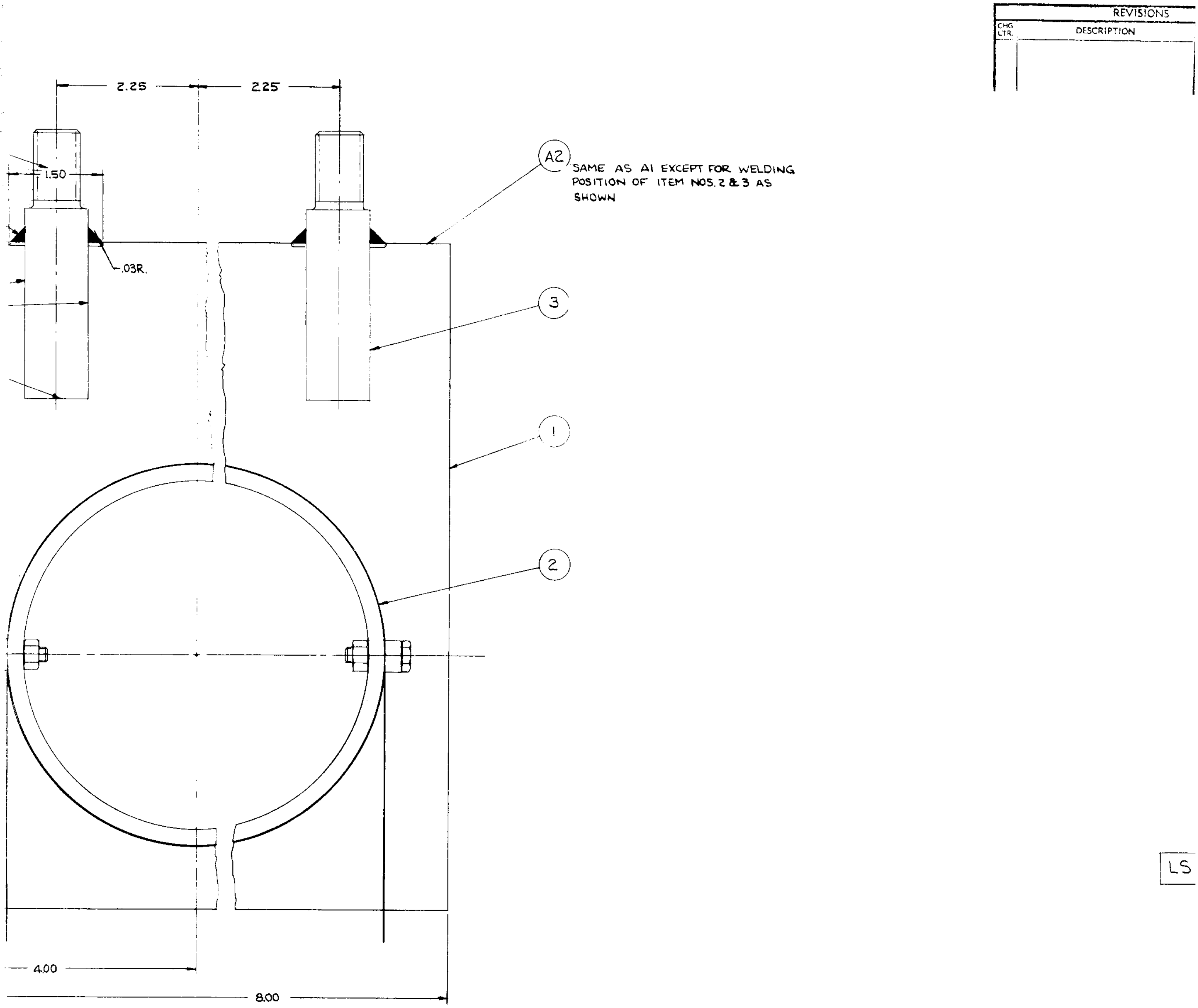


Three Layer Interference Fit

Figure 35



.750-10 UNC 3A
.6806-.6850 P.D.
1.00 DIA.
.7500
.7406
.08 × 45° CHAMFER
1.12 THD LENGTH
1.25
4.25
.06R
2.50
3
.25
5.50
6.03 I.D.
6.00 O.D.
.50
WELDING MATL TO BE HELD WITHIN THIS DIST.
.15
.12
SEE NOTE
.25
2
3.50
OPTIONAL
.38
.023
.013
1.12
.38
4
.25
.03R
.279-.291 DRILL THRU
1 HOLE ITEM NO. 2
1 HOLE ITEM NO. 4
2 HOLES TOTAL
AN104712
BOLT 250-28 UNF3A
AN121502
NUT 250-28 UNF 3B
2.25
HOLD FOR THIS LENGTH
1
1.50
.08 × 45° CHAMFER
.03R.
.25
SEE NOTE
10.50
4.00
4.00
1
A1
A2
A1
AN121502
AN104712
4
3
2
1
A1 A2
A1 A2
A1 A2
ITEM NO.
PART NO.
ASSY.
PART NO.
ADD
REFERENCE



USE SPEC 8178 WELDING WIRE

BREAK SHARP EDGES .005-.015 APPROX R & BLEND

WELD SIZE & LOC DIM. ±.030
FINISHED DIM. ±.010
ALL ANGLES ±2°

ALL NOTES APPLY UNLESS OTHERWISE SPECIFIED

ITEM NO. (ADD)	PART NO. (ADD)	ASS'Y (ADD)	PART NO. (REFERENCE)	PART NO. (CANCEL)	QUAN.	DESCRIPTION	INTERC.	MATL	OTHER SPECS	FORG CAST WR
A2					1	RIG ASS'Y				
A1					1	RIG ASS'Y				
	AN121502				2	NUT - .260-28 UNF 3B				
	AN104712				2	BOLT - .250-28 UNF 3A - .875 LENGTH				
4					2	FASTENER -		AISI 321		
3		A1 A2			2	LUG -		AISI 321		
2		A1 A2			2	CYLINDER -		AISI 321		
1		A1 A2			2	PLATE -		AISI 321		

PARTS LIST

SCALE FULL
JOB NUMBER 7491

DRAWN BY Zawonski — STARTED 10-24-60 — COMPLETED 10-25-60

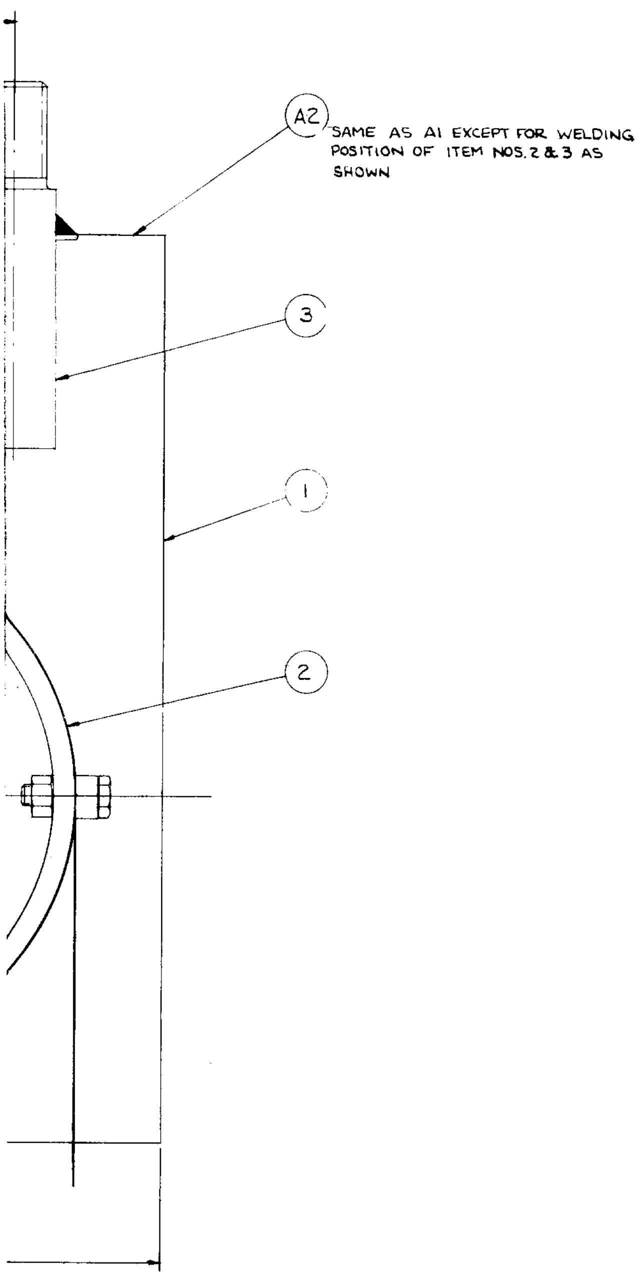
J. L. 10-26-60

CURTISS-WRIGHT CORP.
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE, NEW JERSEY, U.S.A.

INTER-LOCKING TITANIUM
WIRE CASE -
TENSION RIG

Figure 36 Tension Test R

REVISIONS			
CHG LTR	DESCRIPTION	DATE	ENGRS.



LS 25806

USE SPEC 8178 WELDING WIRE

BREAK SHARP EDGES .005-.015 APPROX R & BLEND

WELD SIZE & LOC DIM. ±.030
FINISHED DIM. ±.010
ALL ANGLES ±2°

ALL NOTES APPLY UNLESS OTHERWISE SPECIFIED

DESCRIPTION	INTERC.	MATL	OTHER SPECS	FORG CAST WR
S'Y				
S'Y				
.260-28 UNF3B				
.250-28 UNF 3A -.875 LENGTH				
ER -		AISI 321		
		AISI 321		
ER -		AISI 321		
-		AISI 321		

ITEM NO.	PART NO. ASS'Y / ADD	PART NO. / REFERENCE CANCEL	DESCRIPTION	INTERC.	MATL	OTHER SPECS	FORG. CAST W.R.

PARTS LIST

SCALE FULL
JOB NUMBER 7491
DRAWN BY ZAWONSKI
STARTED 10-24-60
COMPLETED 10-25-60
10-26-60
J. L.
10-26-60
10/27/60

CURTISS-WRIGHT CORP.
WRIGHT AERONAUTICAL DIV.
WOOD-RIDGE NEW JERSEY, U.S.A.

INTER-LOCKING TITANIUM WIRE CASE - TENSION RIG

LS 25806

SH. 1 OF 1 SHEETS

Figure 36 Tension Test Rig

TABLE I

AGING RESPONSE OF B120VCA TITANIUM WIRE

ROOM TEMPERATURE TENSILE PROPERTIES OF "CHANNEL" WIRE

Aging Condition		Ultimate Tensile Strength Avg. KSI	Ultimate Tensile Strength Range KSI	Yield Strength (.2% Offset) Avg. KSI	Yield Strength (.2% Offset) Range KSI	Elongation in 1" Avg. %	Elongation in 1" Range %
As rec'd.	0 hrs.	222.7	221.2-224.2	217.0	215.9-218.1	2.5	2.0-3.0
700°F	10 hrs.	269.0	**267.4-271.0	268.7	***268.5-269.1	1.5	1.5
700°F	15 hrs.	275.9	**274.9-276.9	275.0	274.4-275.8 ***	1.0	1.0
700°F	20 hrs.	271.5	265.2-277.2	270.0	264.6-275.2	2.0	2.0
700°F	25 hrs.	-	**278.8	-	***280.2	0.75	0.5-1.0
700°F	30 hrs.	291.2	***286.0-296.4	290.0	286.0-293.9	0.75	0.5-1.0
750°F	5 hrs.	265.3	264.9-265.7	262.7	262.4-263.0	1.5	1.0-2.0
750°F	10 hrs.	277.7	277.7	273.8	273.8	1.5	1.5
750°F	15 hrs.	276.2	271.6-280.8	274.5	271.0-278.0	1.0	1.0
750°F	20 hrs.	***					
750°F	25 hrs.	-	**287.2	-	***289.4		0.75
750°F	30 hrs.	-	**283.6	-	***293.9	1.0	1.0

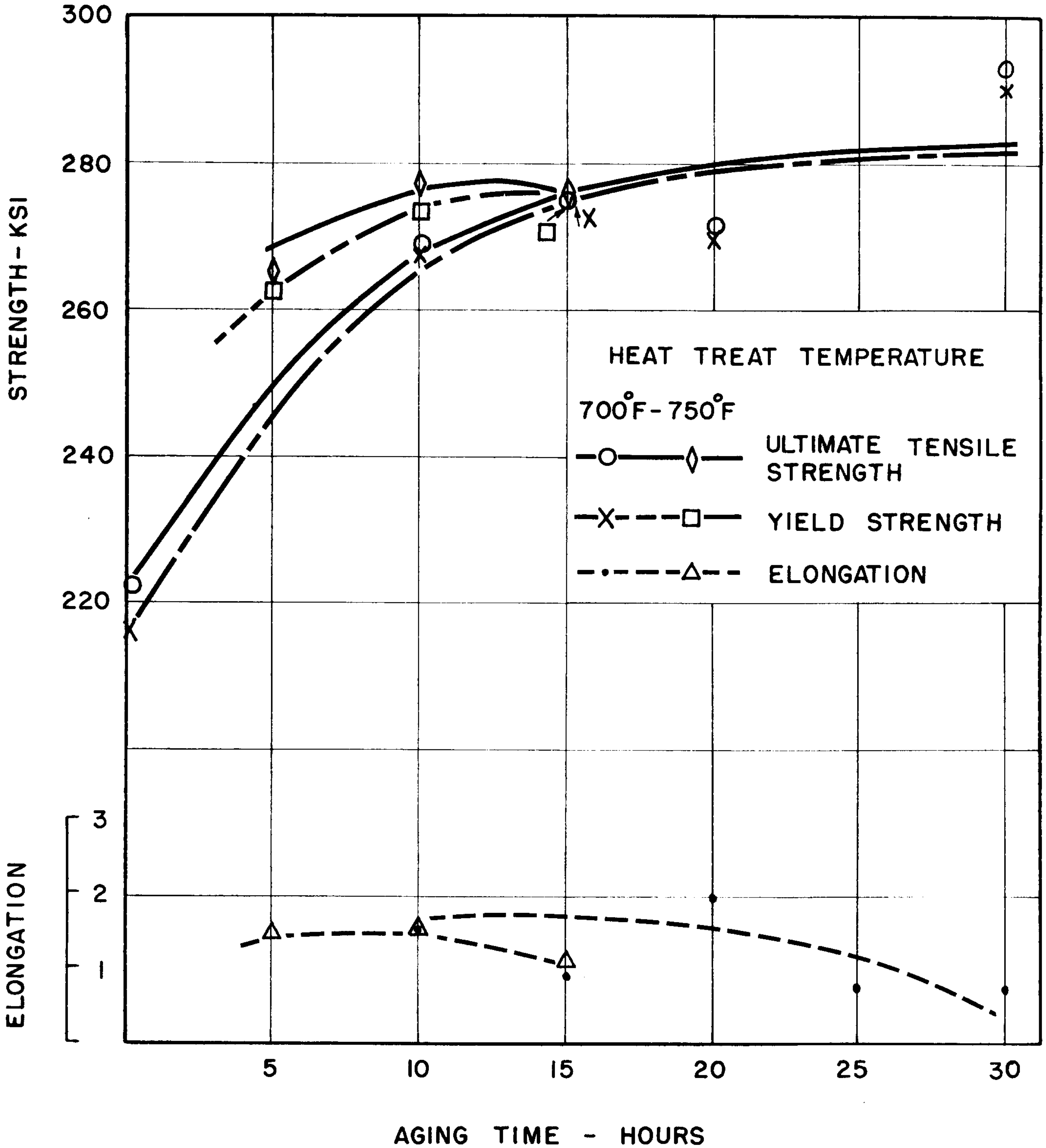
TABLE I (Continued)

Aging Condition		Ultimate Tensile Strength Avg. KSI	Ultimate Tensile Strength Range KSI	Yield Strength (.2% Offset) Avg. KSI	Yield Strength (.2% Offset) Range KSI	Elongation in 1" Avg. %	Elongation in 1" Range %
750°F	38 hrs.	-	**291.1	-	***294.7	0.75	0.5-1.0
800°F	10 hrs.	275.9	273.5-279.7	275.0	274.6-275.5	0.75	0.5-1.0
800°F	15 hrs.	283.0	280.2-285.8	280.5	279.7-281.3	0.75	0.5-1.0
800°F	20 hrs.	269.8	**268.8-**270.8	275.0	***274.4-***275.8	0.5	0.5
800°F	25 hrs.	271.0	271.0	269.1	269.1	1.0	0.5-1.5
800°F	30 hrs.	***					

NOTE: * All wire samples cooled to room temperature in vacuum.

** Sample failed at listed strength which is related to yield strength.

*** Extrapolated value of the yield strength.



300
280
260
240
220
STRENGTH - KSI
3
2
1
ELONGATION
5
10
15
20
25
30
AGING TIME - HOURS
HEAT TREAT TEMPERATURE
700°F - 750°F
ULTIMATE TENSILE STRENGTH
YIELD STRENGTH
ELONGATION

Figure 37

TABLE II

"I" BEAM SHAPE HAVING CROSS-SECTIONAL AREA = $5.0 \times 10^{-3} IN^2$

Aging Temperature and Time	U.T.S. (ksi)	Y.S. (ksi)	Elongation in 1" (%)
As Received (50% cold work)	211.3	204.2	4.0
800°F - 5 hours	246.2	239.75	2.0
800°F - 10 hours	262.5	252.5	2.25
800°F - 15 hours	265.0	254.0	1.75
800°F - 20 hours	263.0	255.5	1.0
800°F - 25 hours	264.0	259.0	--
800°F - 30 hours	263.0	254.5	--
800°F - 38 hours	255.0	--	--

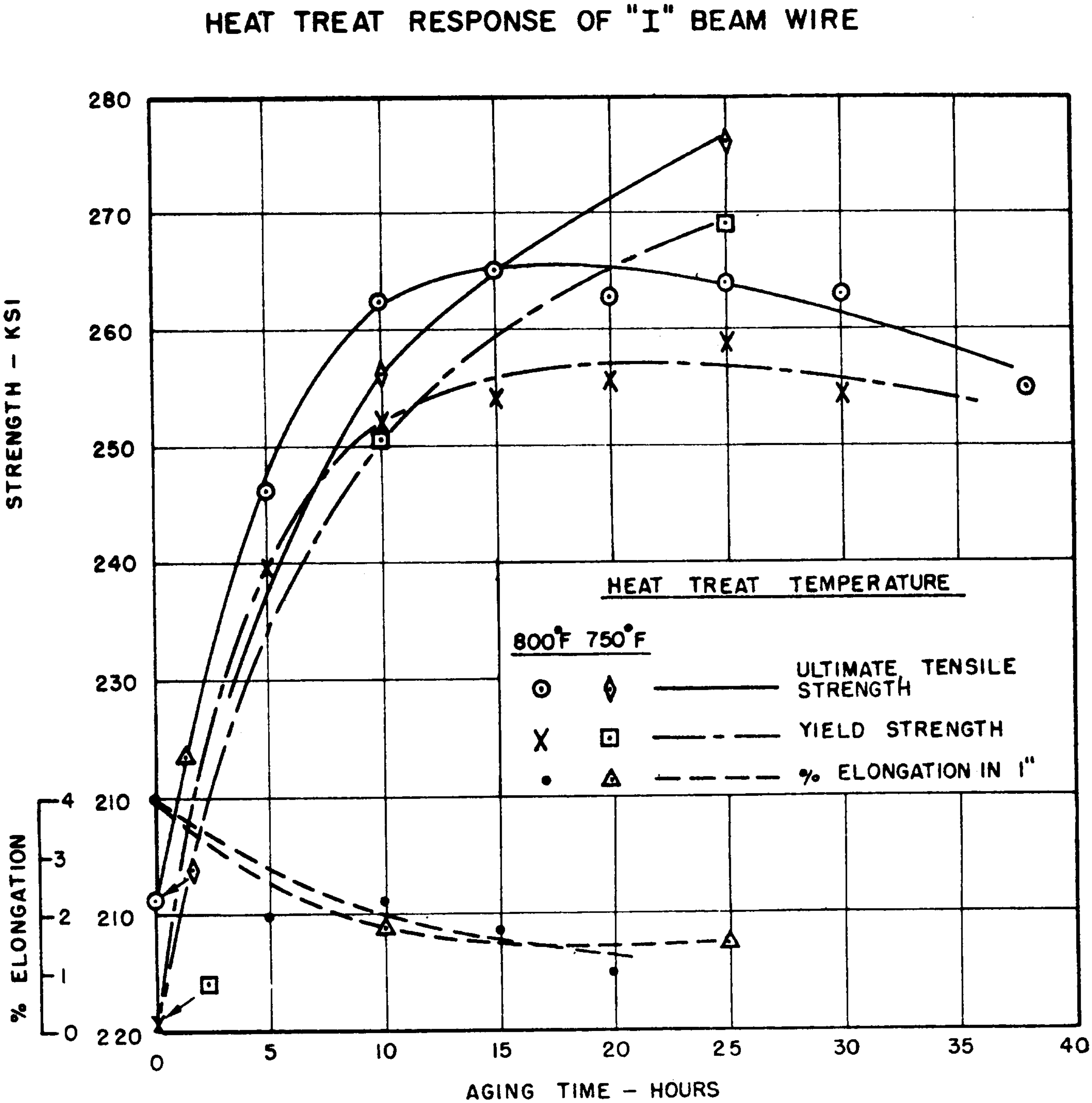
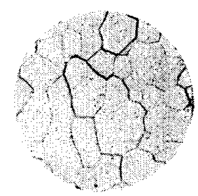
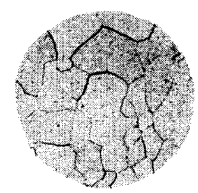
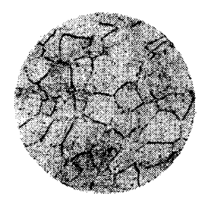
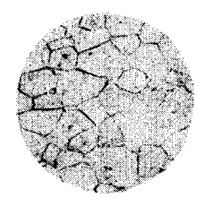
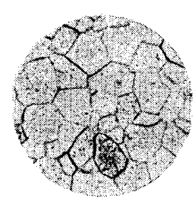
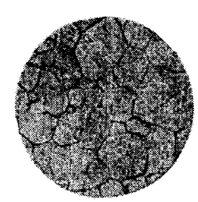

HEAT TREAT RESPONSE OF "I" BEAM WIRE
STRENGTH - KSI
% ELONGATION
280
270
260
250
240
230
210
210
220
4
3
2
1
0
0
5
10
15
20
25
30
35
40
AGING TIME - HOURS
HEAT TREAT TEMPERATURE
800°F 750°F
ULTIMATE TENSILE STRENGTH
YIELD STRENGTH
% ELONGATION IN 1"

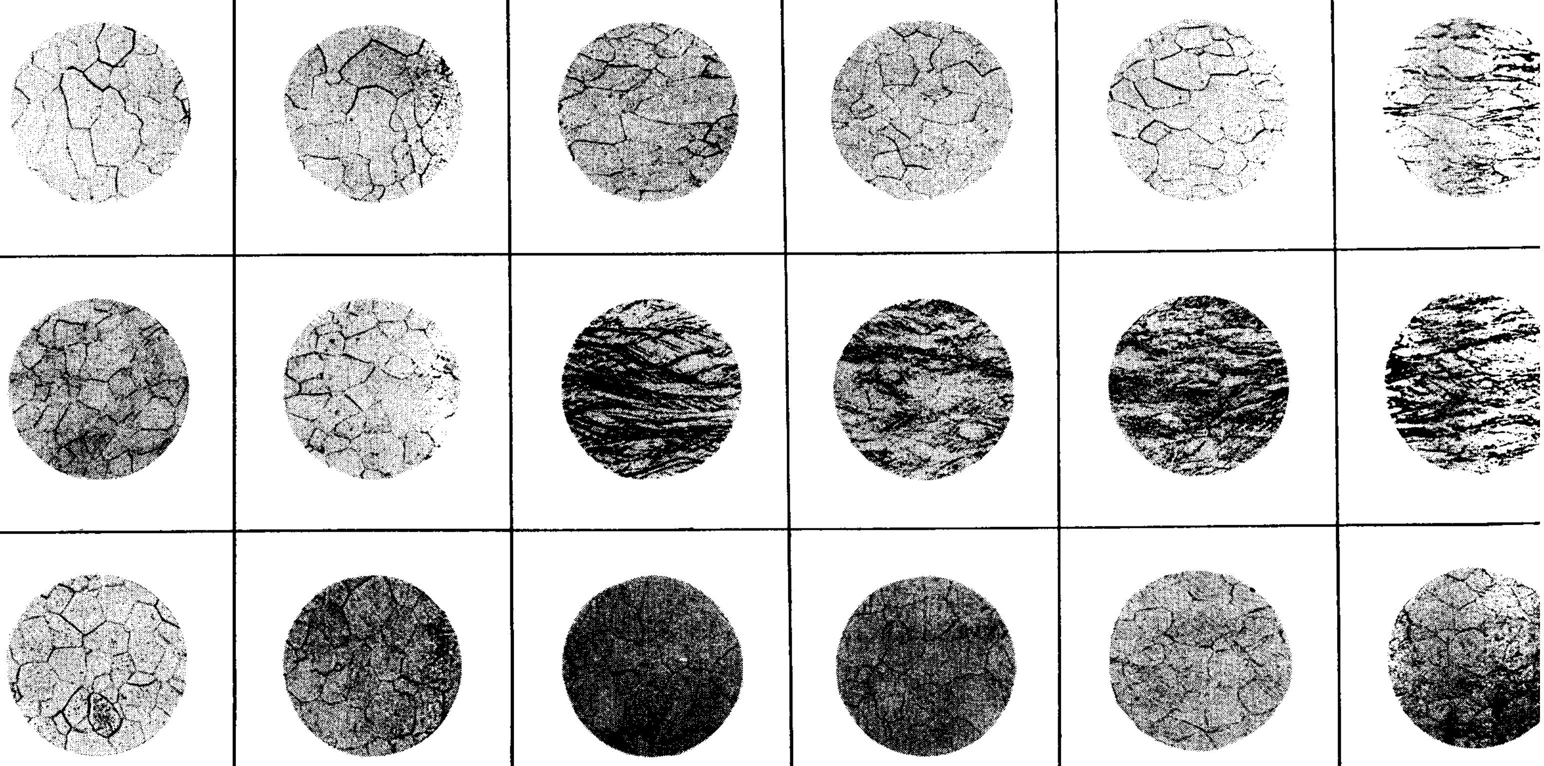
Figure 38

AGING R

MATERIAL CONDITION		
	5.6	5.6
a AS COLD ROLLED		
b AGED 750°F-20 HRS.		
c AGED 750°F-47 HRS.		

AGING RESPONSE VS. % RA

RA (%)					
5.6	5.6	11.8	18.9	25.6	30.0



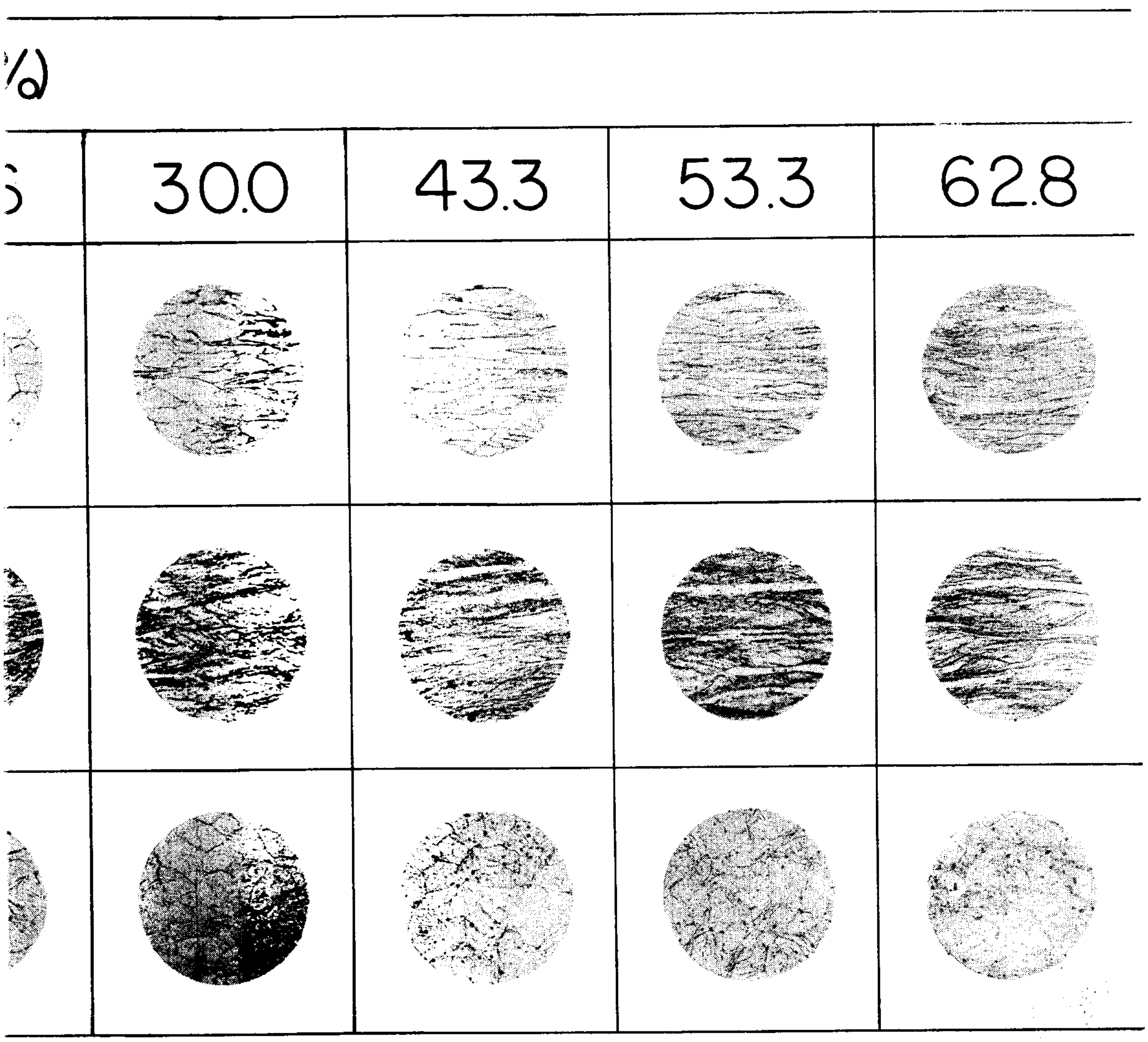


Figure 39

Hardness vs % RA

(750°F Isotherm)

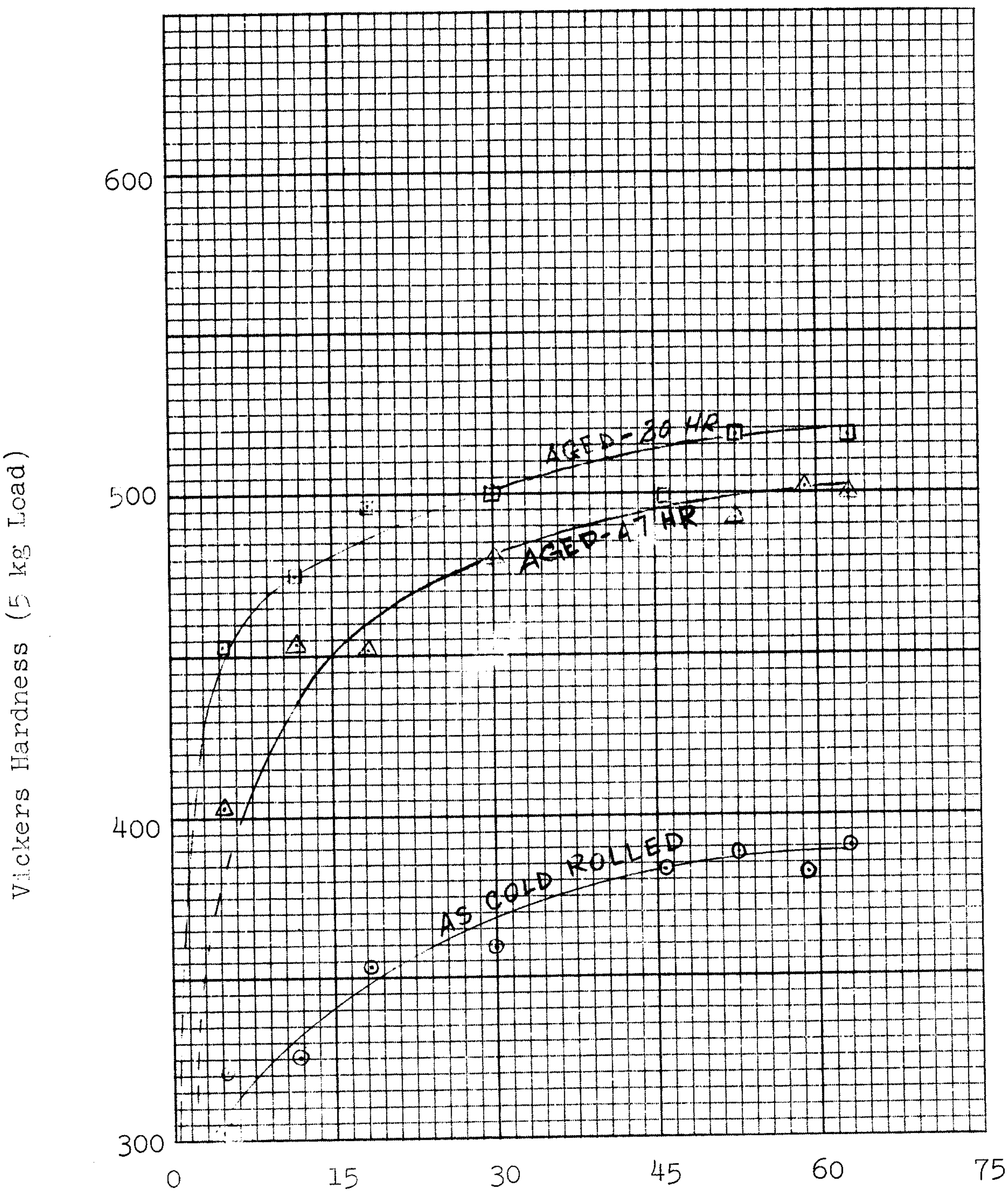
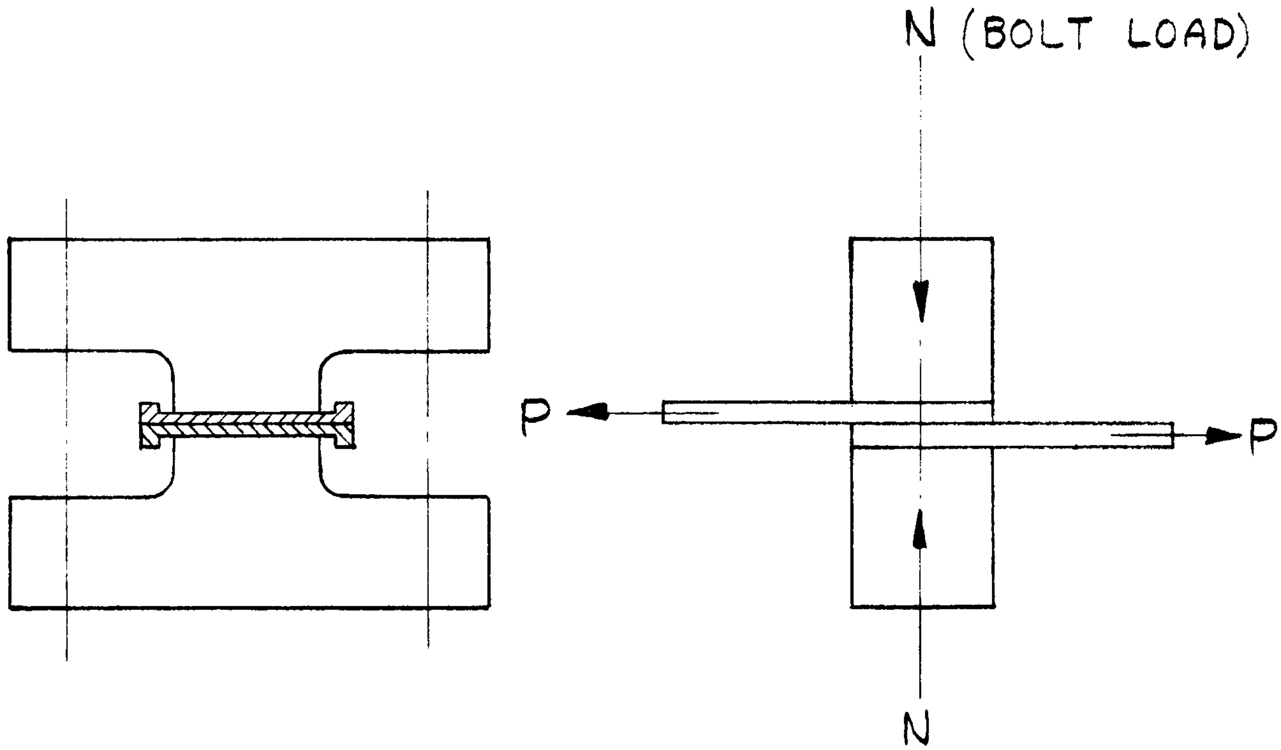


Fig. 40

FRICTION TEST CLAMP



$$\mu = \frac{P}{N}$$

Figure 41

TABLE III

COEFFICIENT OF FRICTION OF B120VCA TITANIUM WIRE

Torque (#)	Nominal Load N (#)	Tensile Load P (#)	Coefficient $\mu = \frac{F}{N}$
	Cold Rolled (Drawn) Wire		
24	1046.9	280	0.267
28	1219.9	360	0.295
34	1480.0	400	0.270
42	1828.2	455	0.249
56	2436.5	660	0.271
			0.270 Avg.
	Cold Rolled, Heat Treated Wire		
24	1046.9	395	0.377
28	1219.9	415	0.340
34	1480.0	510	0.345
42	1828.2	650	0.355
56	2436.5	790	0.324
			0.348 Avg.

RELATIONSHIP BETWEEN THE ANGLE OF WIRE AND COEFFICENT OF FRICTION

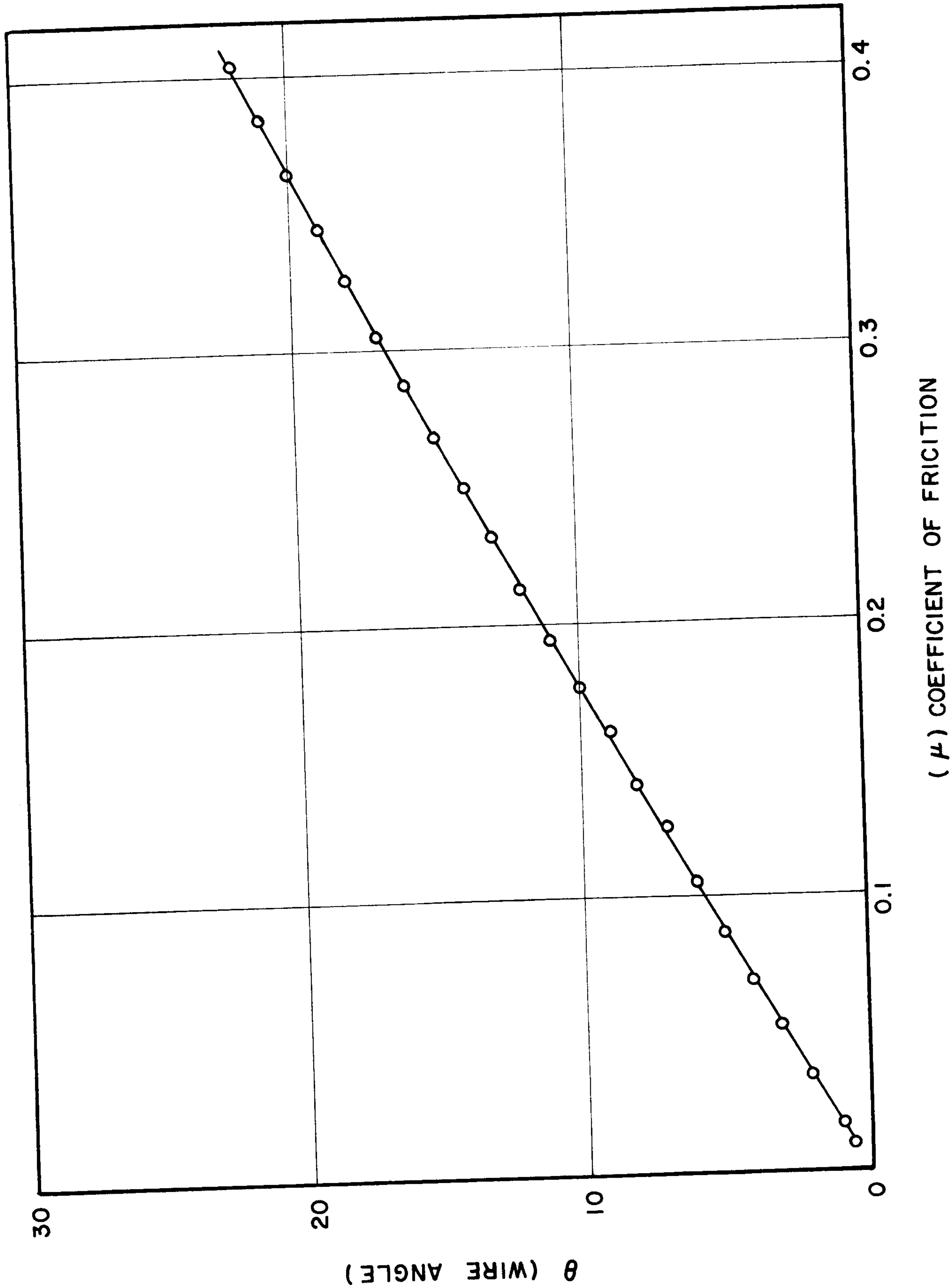


Figure 42

TABLE IV

RESIN EVALUATION

Resin	Shearing Stress (psi)	Modulus of Elasticity ($X10^4$)(psi)
"MARASET" (Marbelette Corp.)	1003	2.04
"BOND MASTER" (Rubber & Asbestos Corp.)	824	1.78
"DEVCON '2 TON'" (Devcon Corp.)	516	1.69

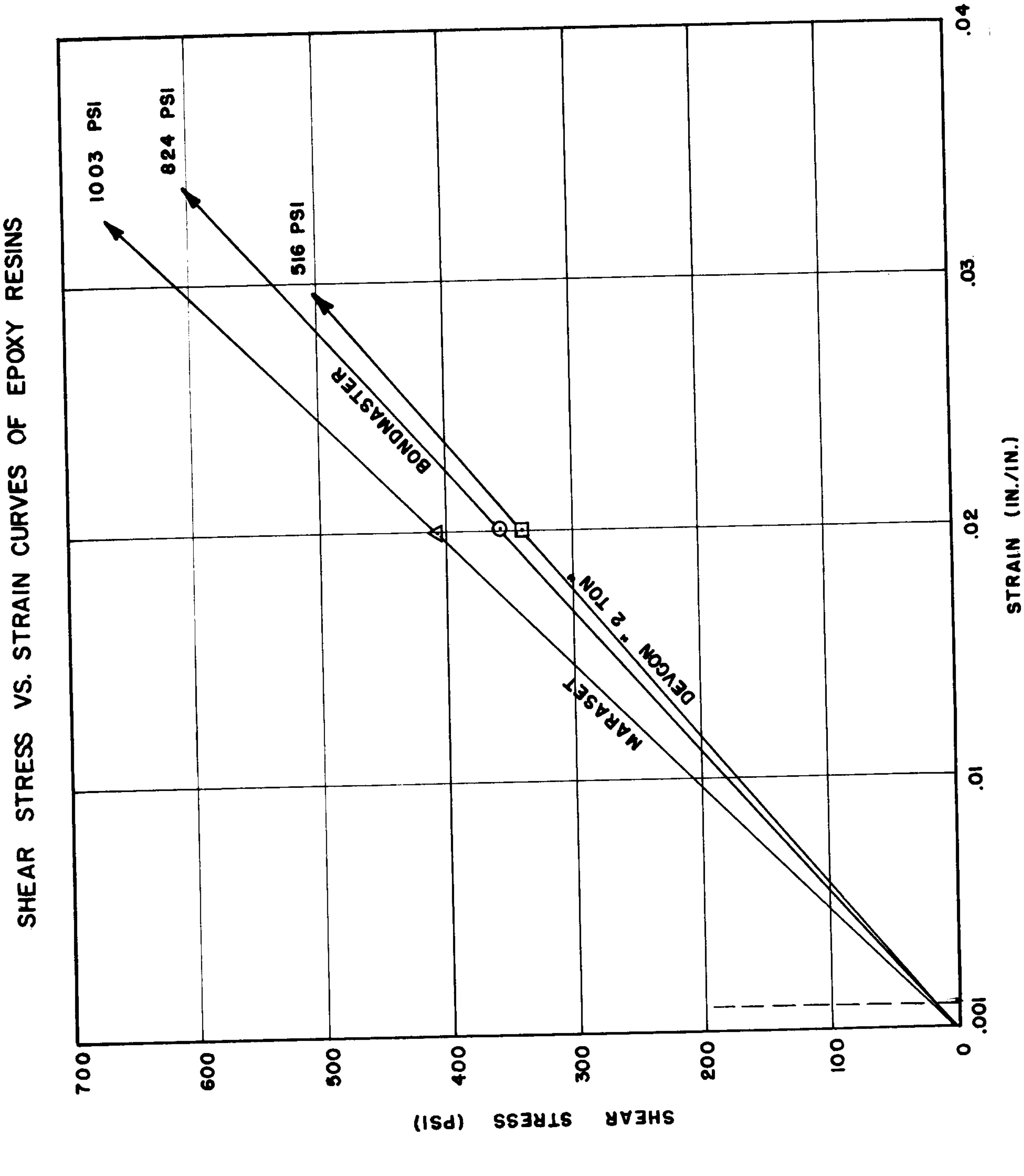

SHEAR STRESS VS. STRAIN CURVES OF EPOXY RESINS
1003 PSI
824 PSI
516 PSI
BONDMASTER
DEVCON " 2 TON "
MARASET
SHEAR STRESS (PSI)
STRAIN (IN./IN.)
0
100
200
300
400
500
600
700
.001
.01
.02
.03
.04

Figure 43

LINER FILM TEST

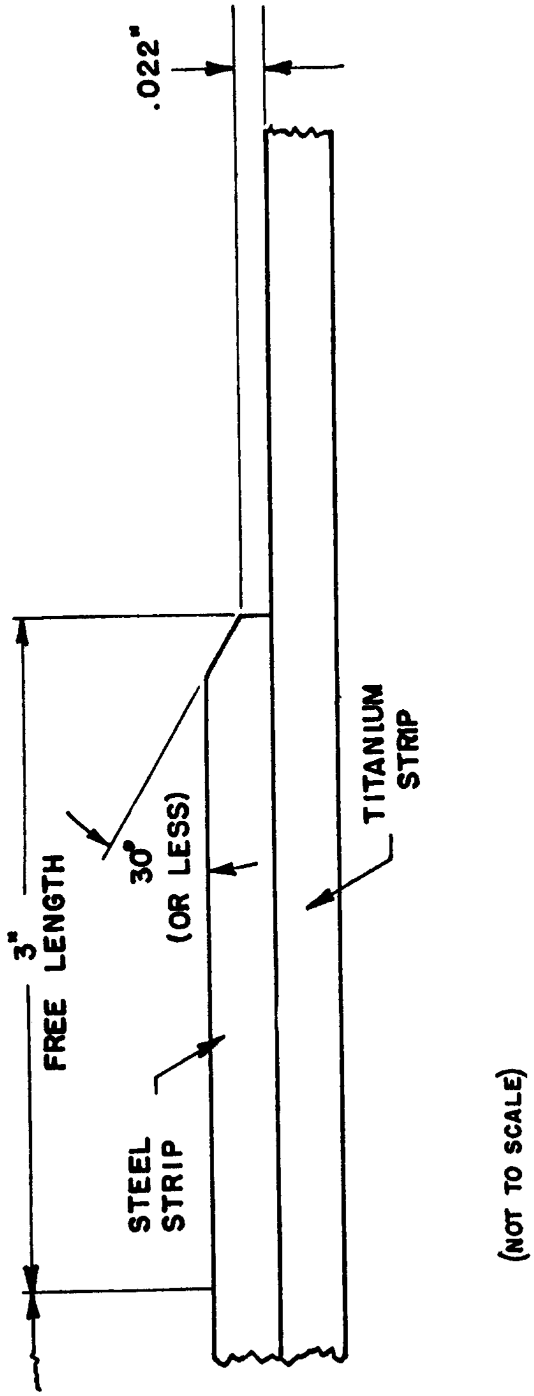


Figure 44

LOW TEMPERATURE TENSILE PROPERTIES
OF
B120VCA Ti - AGED AT 900°F - 75 HRS.

AC (HEAT #F-6236 - GAGE - 0.090")

Test Temperature	Condition	UTS	Elongation in 1" (%)	RA (%)	RATIO: Notched UTS / Smooth UTS
Room Temperature	Smooth	214.0	3.4	4.9	0.78
	Notched	164.1	1.0		
-35°F	Smooth	220.6	1.5	3.1	0.61
	Notched	135.5	.3	0.5	
-65°F	Smooth	227.2	1.2	1.5	0.57
	Notched	129.5	.05	0.1	
-110°F	Smooth	235.8	1.0	0.5	0.52
	Notched	121.5	0	0	
-320°F	Smooth	190.0	0	0	0.34
	Notched	64.0			

FIG. 45

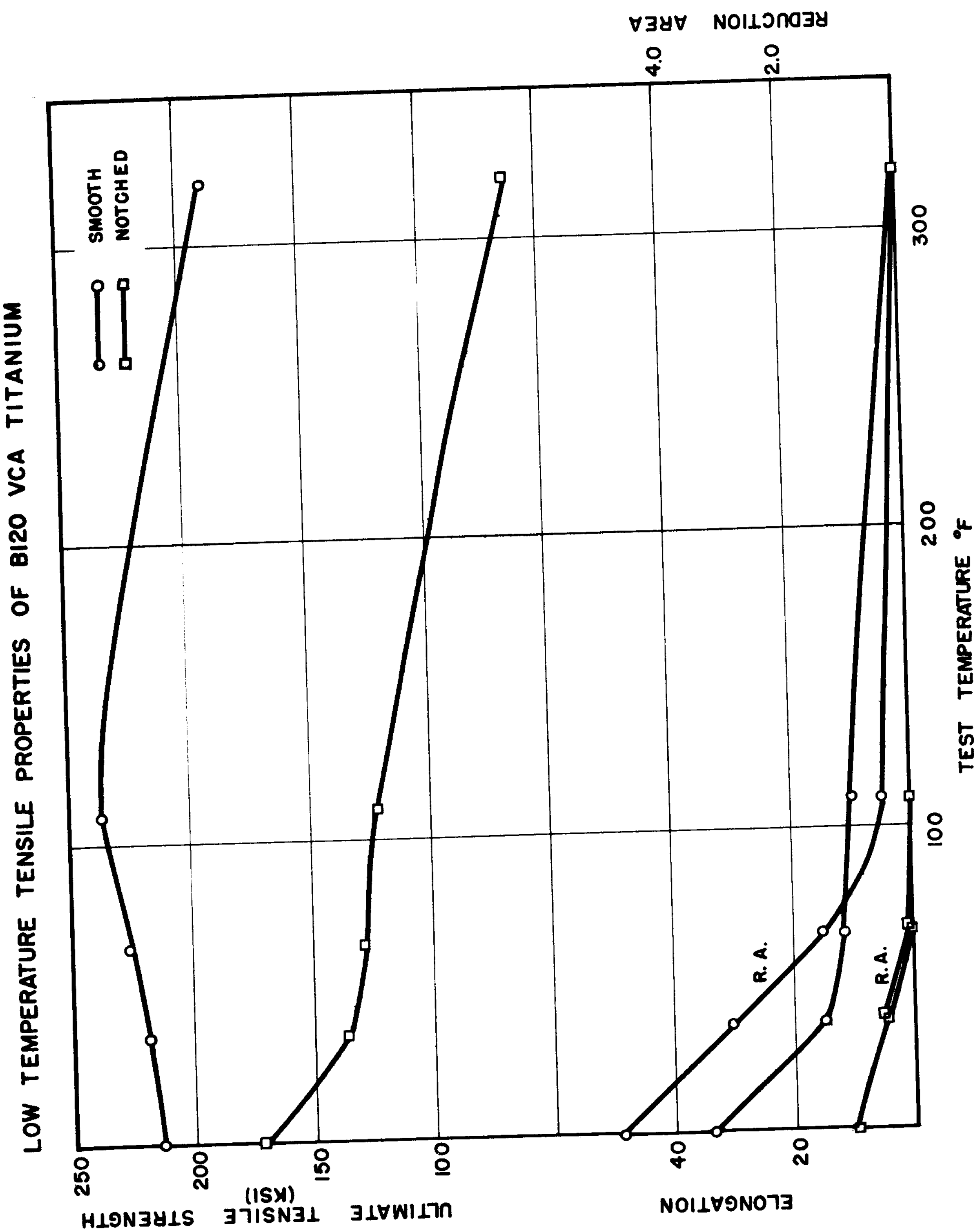

LOW TEMPERATURE TENSILE PROPERTIES OF BI20 VCA TITANIUM
SMOOTH
NOTCHED
ULTIMATE TENSILE STRENGTH (KSI)
250
200
150
100
ELONGATION
40
20
REDUCTION AREA
4.0
2.0
R. A.
R. A.
100
200
300
TEST TEMPERATURE °F

Figure 46

6.0 EXPERIMENTAL MANUFACTURING

6.0 EXPERIMENTAL MANUFACTURING

The manufacture of two 6.2" I.D. sub-scale vessels, employing the tape configurations illustrated in Figures 3 and 4, was accomplished on a converted lathe shown in Figures 47 and 48. This piece of equipment consists of the following components:

(a) Wrapping Apparatus (6T-60924)

(b) End Adapters (LS-25439-7)

(c) Collapsible Mandrel (6T-60925)

(d) Reel Equipment (6T-60988)

(e) Dummy Arbor (DA-32360)

6.1 Wrapping Apparatus

The wrapping apparatus (Figure 49) rolls over the mandrel assembly (described in the following section) on the ways of the lathe. It is initially supported on three legs. The apparatus is fitted with three equally spaced and free rotating rollers. Two of the rollers are mounted on shafts which are clamped to the frame and the third is mounted on a cylinder. This system is capable of applying a rolling radial force of 2500 pounds on the tape. By application of the rolling force, the apparatus lifts from its legs and centers itself on the mandrel. The roller shafts are axially and angularly adjustable by means of gage blocks and sine bar devices mounted at the shaft ends (Figure 49). This provides a means of tilting the rollers to the wrapping helix angle while maintaining their correct axial positions. A spring loaded guide pushes the tape axially at the point of tangency as the tape is fed on the mandrel. Three sets of rollers are required to wrap a vessel. Each set of rollers is formed to suit the particular tape shape. The apparatus is attached to the compound of the lathe carriage through tie rods for driving through the lathe lead screw. This provides axial and square adjustment of the apparatus while it is engaged in the lead screw pitch. By removing the tie rods, the apparatus may free-track to follow the pitch of a tape lay.

Trail wrapping was attempted with spring loaded tie rods pulling the head in the anti-wrapping direction with forces which are great enough to overcome the friction between the tape and the arbor. The tests were unsuccessful since the

6.1 Wrapping Apparatus (Continued)

rollers pulled out of the tape track. The rollers were subsequently reworked to remove the .010" radii at their edges. Another trial run showed them to still roll out of the tape track. It was then concluded that the head must be able to track freely, uninhibited by external forces.

The tie rods were removed and the same tape was wrapped with the head tracking freely. The roller helix angle or tilt was set for .190" pitch or .010" less than the channel width. As the channel winds on the arbor, it is continuously pushed at the shoulder by the difference in pitch, which causes the tape to slip on the arbor until it butts the previous wrap (Figure 50). After butting is achieved, the roller slips on the tape to make up for the pitch difference. This is a continuous and smooth occurrence since the displacements are achieved in the circumferential length of 20 inches in each turn. The first trial of 14 wraps measured .011" more than 14 times the mean width of the channel. A second trial with a more uniform channel was wrapped 17 turns with a measured length of .0005" more than 17 times the mean tape width. This method of wrapping is considered acceptable for the first layer.

Trial wrapping of the second layer was first attempted with an embrittled tape section which failed under load. A second attempt was made using a unheat-treated length which distorted under a load of 1500 pounds and required 500 pounds to bottom on the first layer. The second layer was wrapped successfully with a 1000 pound radial load, but the interference fit was not sufficient for full interlock.

The third layer was similarly wrapped with a 1000 pound radial load. The three layers shown in Figure 51 were wrapped on the dummy arbor demonstrating that the wrapping technique, except for increased interference fit, is feasible.

6.2 End Adapters

300M and SAE 52100 steel end adapters are rough turned, heat treated, and ground all over. All helical surfaces are ground on a thread grinder in the solid stock. The grinding of the inner tape is done after assembly in order to maintain adapter strength during wrapping and mandrel stripping. The technique developed for grinding the helical surfaces utilizes a set of wheel dressing cams which provides a "V" shaped wheel edge with a 24° included angle. The point is dressed down so that

6.2 End Adapters (Continued)

the wheel grinds a groove of .0544"-.0536" width when fed to a sufficient depth. The adapter is clamped on an arbor (Figure 52) which has angular scribe marks to permit rotation and re-indexing of the adapter relative to the wheel and arbor which are constantly engaged in the machine's .200 pitch. In this manner, control of the pitch is maintained while the same wheel is relatively shifted from position to grind the other groove shapes which are off the pitch lines.

A comparator chart of 62-1/2 magnification was used to check the helical surfaces on an optical comparator.

The grinding of the inner taper is done after assembly in order to maintain adapter strength during wrapping and mandrel stripping. A support tube (Figure 53) was designed and fabricated which clamps the adapters of a finished vessel. This tube supports the vessel during grinding of the tapers and also acts as a protective case for the vessel.

6.3 Collapsible Mandrel

The end adapters are assembled and clamped on a mandrel (Figure 54) which holds them in position and provides a core for wrapping. This mandrel is capable of absorbing the wrapping loads and is collapsible and retractable after wrapping. It consists of a solid stepped shaft (Figure 55) onto which a five-segment shell is assembled. The segments were made from two hardened cylinders which were ground on the I.D. to fit the center shaft and on the O.D. at each end to fit the counterbore in the locating rings. The segments are clamped to the shaft by means of the locating rings which are piloted on the shaft and are in turn clamped in the assembly. The end adapters are assembled on the locating rings and held axially between the segment's shoulders and end plates. The adapters are free to rotate for angular positioning by adjustment of the end plates. In disassembly, the end plates are removed and one locating ring removed by pull-out screws. The assembly is located on a sleeve which permits the pressing out of the shaft which in turn pushes out the second locating ring. The pressing load is opposed by the reaction load passing through the sleeve, the end adapter, and the segments. The segments are then free to be pulled to the center and withdrawn. During wrapping, the mandrel assembly is driven on a lathe between the face plate and a live center (Figure 56).

6.3 Collapsible Mandrel (Continued)

The extraction of the mandrel, after wrapping, required approximately a 10,000 pound force. This was resulted in the draging of the tape causing a "saw-tooth" effect. In view of this, a new inner core was designed and constructed for the collapsible mandrel. The new core incorporates a 1/16 inch thick "Cero Alloy" sleeve which will be melted before extraction of the core, and thus reduce the extraction force.

6.4 Reel Equipment

Reel equipment is mounted on the lathe head and locates the tape reels in the axial location of the mandrel. Each reel (Figure 56) holds enough tape for one layer and spaces it to the wrapping pitch. The reel is mounted on a shaft shich is supported between bearings (Figure 57). A drag brake is mounted at one end of the shaft and is controlled by a potentiometer which can vary the tape tension in a range of 0-400 pounds.

6.5 Dummy Arbor

A dummy arbor (Figure 58) which simulates a mandrel assembly with end adapters has been designed and fabricated. This is a hardened, solid steel arbor which is used in the development of wrapping procedures. Variables due to tape tolerances and assembly of parts are minimized so that the adapters and mandrel are not jeopardized during development.

6.6 Staking

This method of joining the tapes to the adapters includes drilling for pins in the hardened tape and adapter material on a sensitive drill. The drilling must be done at the wrapping machine with a hand drill which presents risk of drill breakage. The drilling of the end adapters requires solid carbide drills which are extremely brittle. The staking pin size has been increased to 1/16" to reduce drill breakage.

6.7 Wrapping Development

Trial wrappings of the first layer were made with the roller helix angles set for .200" pitch and the wrapping head driven by the lathe lead screw. The resulting spacing was erratic. The first layer must be wrapped with channels butting tightly to permit fitting of the second layer interlock. Several modifications were made to the wrapping apparatus primarily for this

6.7 Wrapping Development (Continued)

purpose. The probability of tape width, the head tracking rate, and the lathe lead being exactly the same is remote. Therefore, axial slippage is expected and should be used to advantage. Fixing of the head to the lathe lead screw, as originally contemplated, is not considered practical.

Experiments were then run with the wrapping apparatus on the bare dummy arbor using various roller helix angles and radial loads. An inconsistency in the tracking rate was detected. Eccentricities in the roller shaft assemblies and deflections in the apparatus due to machining tolerances and roller loads were noted. Corrected base line settings on the shaft assemblies were established to minimize the effect of these deviations.

Experiments were also carried out to determine the axial drag force required to overcome the clamping load of the rollers on the bare arbor. The apparatus was set to track the arbor by means of roller tilt and clamping load. Cables, fitted with a spring balance, were attached to the frame and fixed at opposite ends. The apparatus tracked the mandrel until the restraining force of the cables caused slippage between the rollers and the arbor. Coefficients of friction between .120-.126 were realized. A similar test was run with short pieces of channel tape located between the rollers and the arbor, but without rotation of the arbor. The drag force indicated a coefficient of friction of.5, approximately.

A modification was made on the wrapping apparatus which incorporated a third tie rod between the wrapping head and the lathe compound (Figure 59). The three equally spaced rods were fitted with springs and preloaded to pull the head back from the wrapping direction, thereby stacking the first channel tightly with a predetermined load.

In previous trial wraps, the radial forces used were 500, 1000, and 1000 pounds for the first, second, and third layers, respectively. The tape tension remained at 200 pounds.

No problems were encountered during the dummy arbor wrapping of the first layer. The second layer ("I" beam), however, fractured under the 2500 pound load on the first few laps over that portion of the cylinder equivalent to the adapter piece. The load was reduced to 1000 pounds over the adapter portion and then increased to 2500 pounds over the titanium-to-titanium interlocking sections without further cracking. The third layer was wrapped using a 500 pound load on the steel and 2500 pounds on the titanium without difficulties.

6.8 Wrapping Vessel No. 1

Vessel No. 1 (Figures 60 and 61) was wrapped, staked, and the mandrel successfully withdrawn. The force necessary to withdraw this mandrel was 10,000 pounds. This vessel appeared to be rigid and able to withstand handling despite the following condition:

(a) A variation in outside diameters between the end adapters and the mandrel resulting in an adapter to mandrel step. Wrapping difficulties occurred in these zones on all three layers. It is felt that this situation caused a "saw-tooth" effect on the inside of the vessel when the mandrel was extracted.

(b) The tape used (both "I" beam and channel) was slightly out of tolerance.

(c) An incorrect "as-received" helix on the third layer increased the tendency of this tape to eject the staking pins. This incorrect helix also caused the tape to form an "S" shaped curve coming off the wrapping reel. This condition produces difficulty in attaining a tight loop-to-loop (side face) contact. It was learned from these problems that the third layer (channel) must be wrapped during the tape manufacture process onto the drum with the legs facing inward.

Wrapping of the first layer employed the proper shaped rollers loaded to 500 pounds radially with a tensile force on the tape of 200 pounds. These rollers were free-tracking and were set at a retarding pitch of 0.190 inch; the wrapping pitch being 0.200 inch. The proper angular alignment (about its axis) of the terminal end-adapter was accomplished using a "Jo" block of a thickness equivalent to a multiple of the actual channel tape width. A gain of .001 inch in width for each turn due to the compressive deformation of the tape was measured resulting in a cumulative total terminal loss of .043 inch for the complete first layer. No measurable space between turns was observed. An "Indiac" concentricity measuring device showed maximum runout of 0.002 inch except in the adapter-to-mandrel transition areas where the step caused the instrument to run off scale.

The second layer, rolled with wide, plain rollers, cracked under the imposition of the high (2500 pounds) radial force.

6.8 Wrapping Vessel No. 1 (Continued)

A check of the end adapters revealed that the adapter section which fits into the groove of the "I" beam was wider than the tape groove and that sharp edges existed. By breaking these edges, the interference fit was reduced and cracking eliminated. This second layer was removed and, using new tape (having the same cross-section), rewound under a radial force of 1350 pounds.

The third layer (channel) also was confronted with the "step" problem. In addition, the application of the high radial rolling force (2500 pounds) plastically deformed the tape thus increasing the basic width of the channel by .0014 inch. The first few loops were unwound and the tape width reduced to 0.200 inch by hand filing. Pressure tests on subsequent wraps indicated that a gage setting of 45 psi (1300 pounds approximately), applied radially, was the optimum non-deforming force permissible. This setting was used to complete the wrapping of the third layer.

6.9 Wrapping Vessel No. 2

The first layer was successfully wrapped with a radial load of 570 pounds and tensile load of approximately80 pounds.

The second layer bottomed and locked with a radial load of 870 pounds and a tensile load of 80 pounds. A radial load of 1000 pounds caused distortion. Towards the end of the second layer at the terminal point of the first layer, a space developed between the first layer and the end-adapter shoulder. The staking pin for the first layer was removed, the adapter was rotated to close the space and wrapping of the second layer was completed. The space could be caused by a .0002 compression of the channel tape in the interference fit. The tape used in this vessel was not heat treated.

The third layer required a 1200 pound radial load and a 180 pound tensile load. No difficulties were encountered until the channel reached the first groove on the end adapter, at which point it was displaced approximately .005 forward. The last wrap had to be filed to fit.

After completion of wrapping and staking, the collapsible arbor was removed on an arbor press with no difficulty. The arbor extraction force was estimated at 5 tons. The inner tapers on the end adapters were machined to finish the vessel.

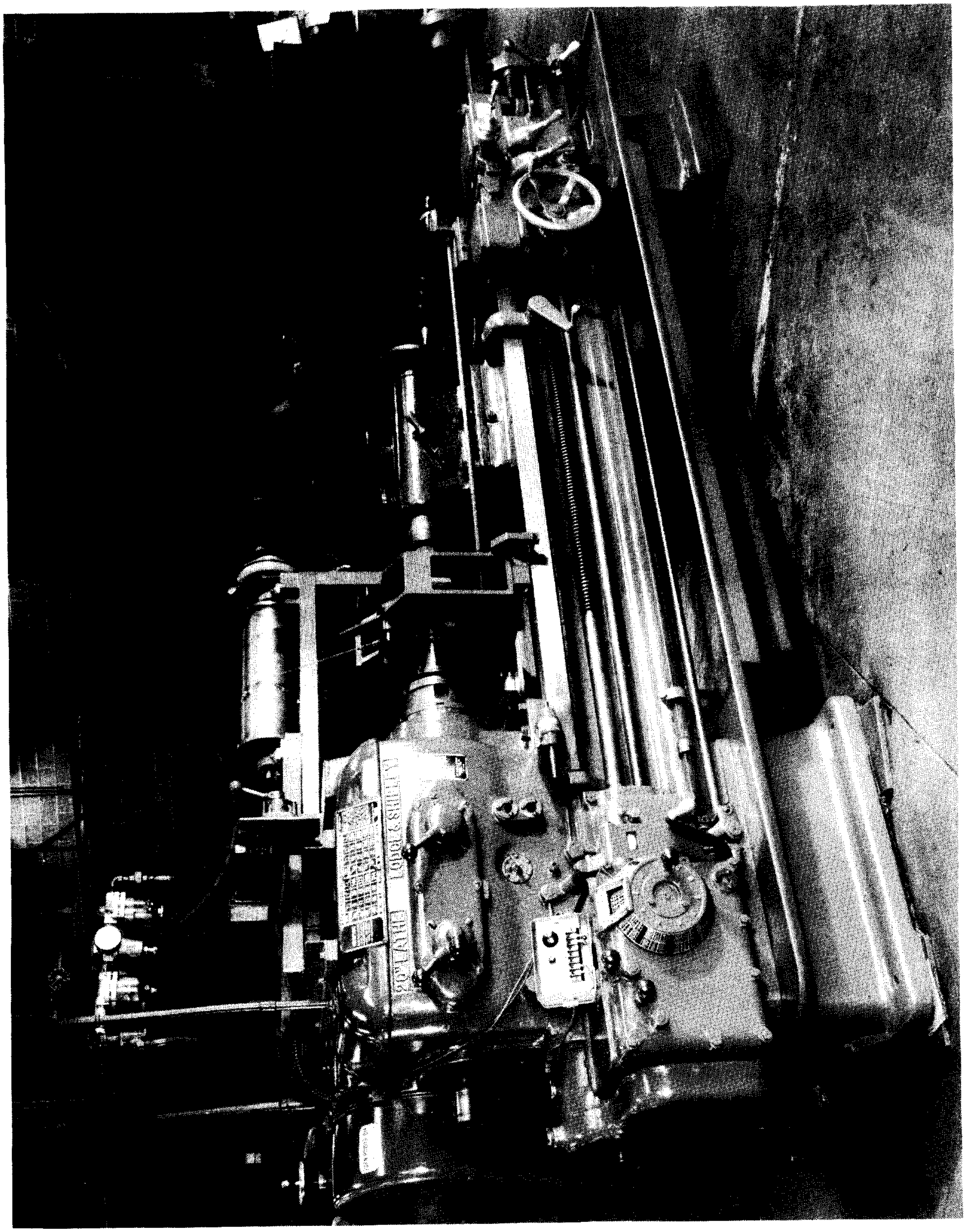
6.9 Wrapping Vessel No. 2 (Continued)

The finished vessel was approximately .020" smaller in diameter at the center than at the ends with .004" total runout of the end faces. The outer diameter remained smooth but the inner bore was slightly stepped in a manner resembling rifling. This indicates that the interlock between the 1st and 2nd layer is incomplete.

Generally, the wrapping was indicative of the feasibility of the technique. Better results are expected with more accurately sized tape with the required strength and ductility.

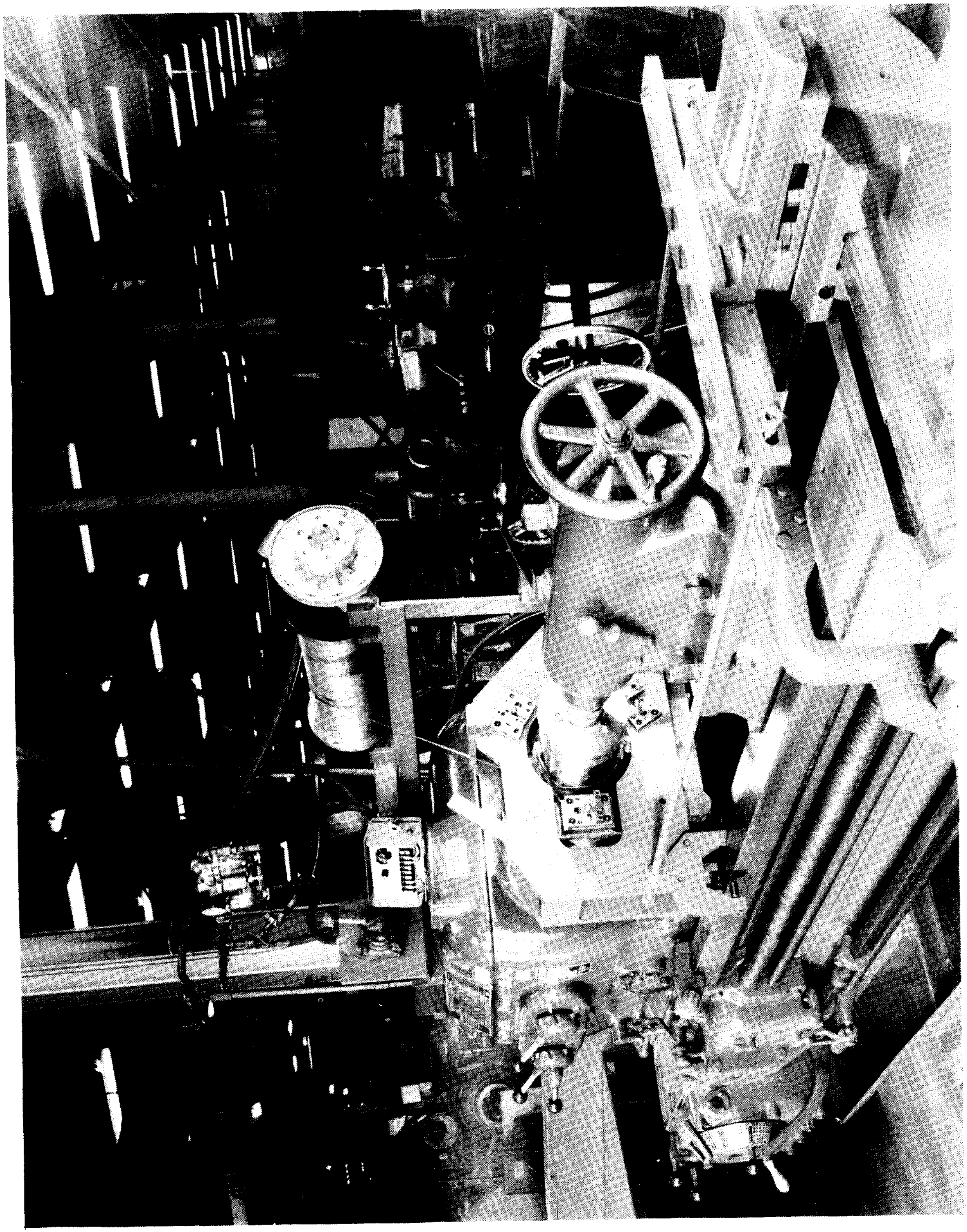
This vessel pressurized and leaked at 30 psig. The leak was caused by a separation of the tapes at one end of the vessel. Since the separation occurred near the edge of the end adapter, it was surmised that the flaw was caused by a compression of the end adapter as the mandrel parts were being withdrawn. The tensile force on the tape during wrapping imposes a hoop stress which is transmitted to the end adapters and the mandrel as a radial compressive force. As each portion of the mandrel is removed, the vessel contracts in that area. The first portion removed is located under the adapter near the point of failure. However, a good interlock between the tape layers should hold the vessel intact until the remainder of the mandrel is withdrawn. A modification on the mandrel could be made to permit a collapse prior to withdrawal.

This separation was plugged by casting an inner and outer shell of a low melting alloy. A second test was conducted which resulted in failure at 50 psig. The vessel separated in the center section far from the end adapters. The tape layers unwound easily indicating a lack of interlock. These sectional radii and the locking angles were enlarged and the 'I" beam was found to be twisted. It appears that after wrapping when the mandrel was withdrawn, the wrapping stresses were relieved by contraction of the vessel. The "I" beam twisted toward its free position (Figure 62) and a stagger "tooth effect" developed on both the O.D. and the I.D. of the vessel. It is suspected that the tape layers were not bottomed and the interlock was insufficient to prevent twisting.



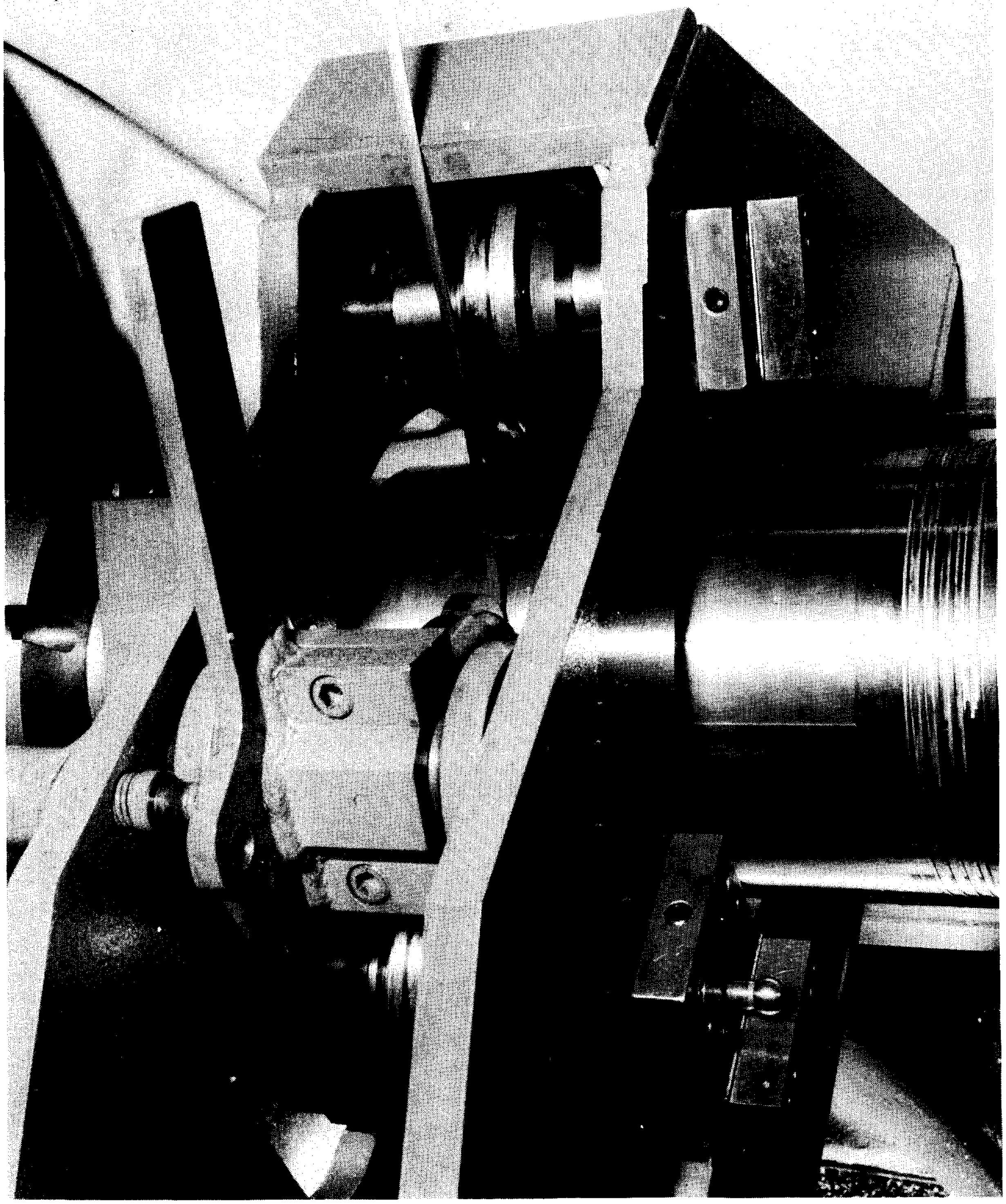
Tape Wrap Machine

Figure 47



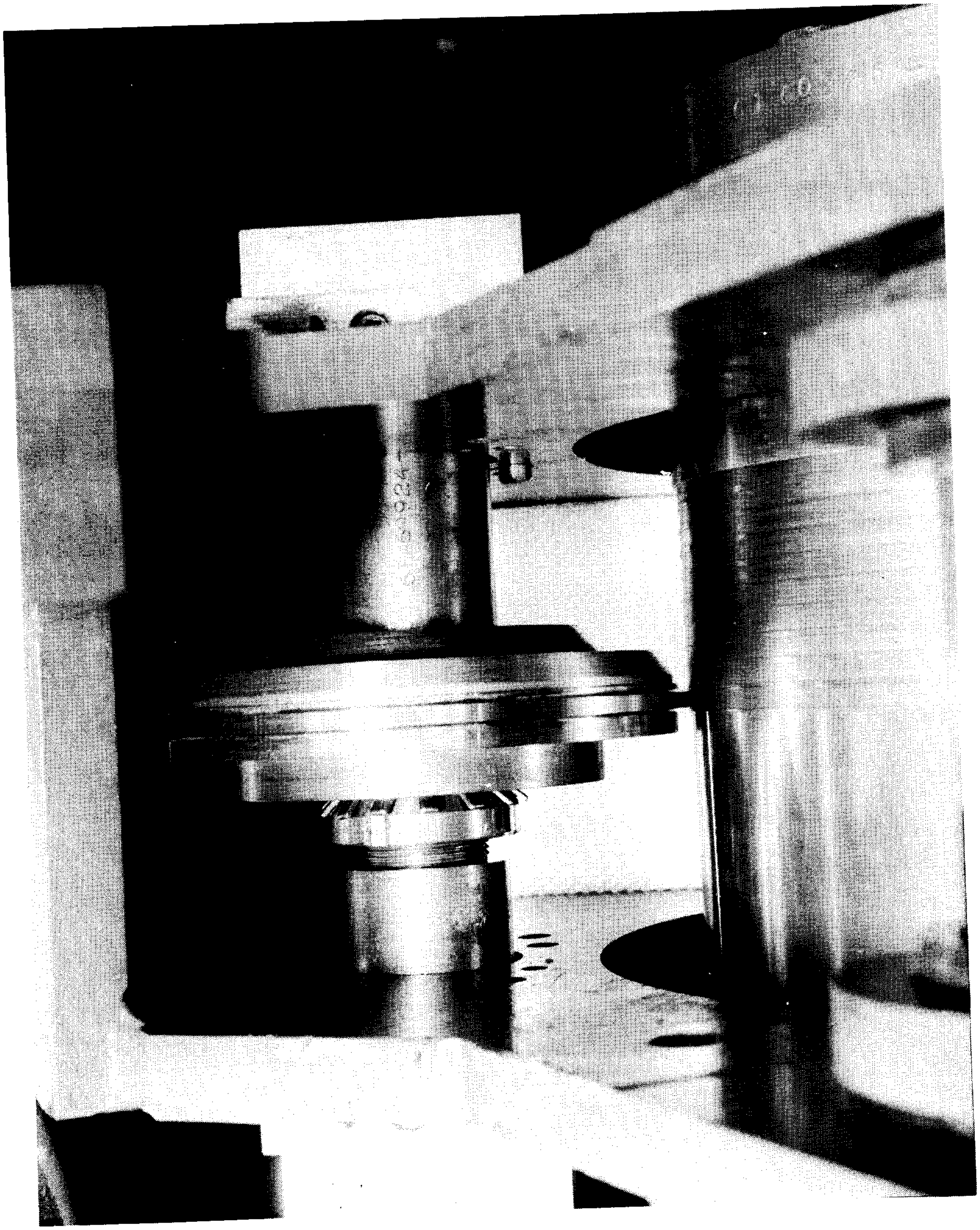
Wrapping Apparatus Close-Up

Figure 48



Wrapping Apparatus

Figure 49

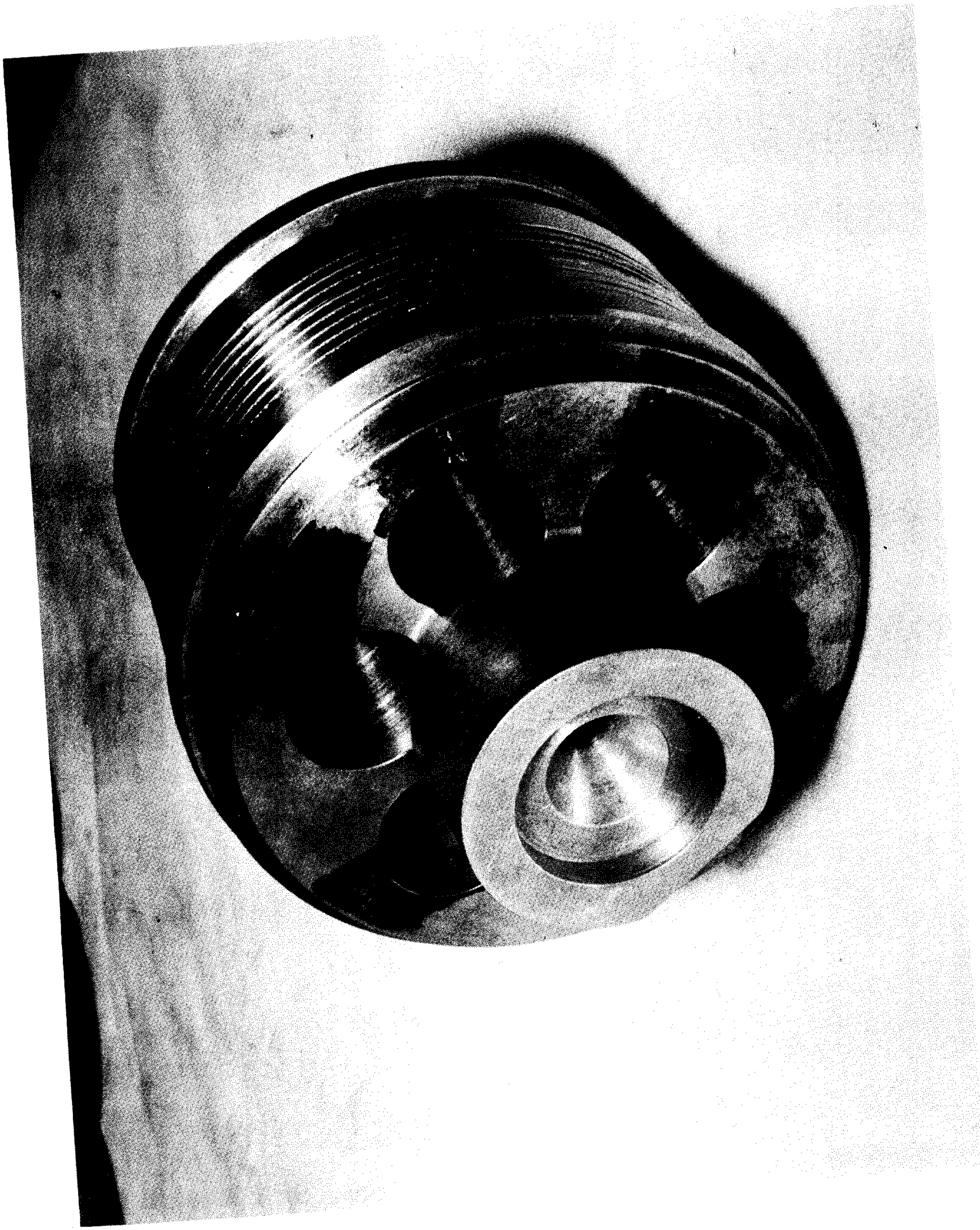


Close Up of Roller on Channel Wire

Figure 50

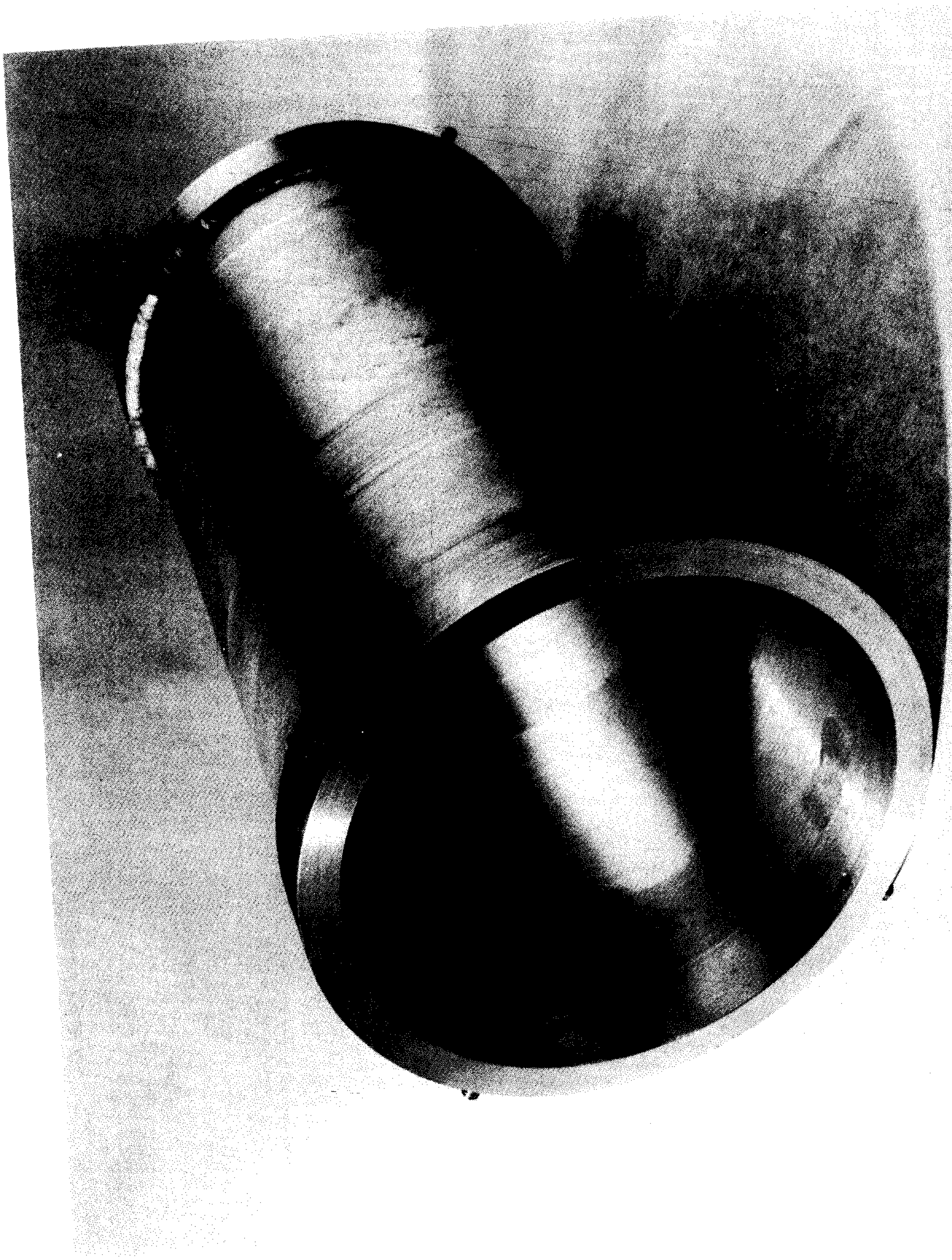
Three Layers Wrapped on Dummy Arbor

Figure 51



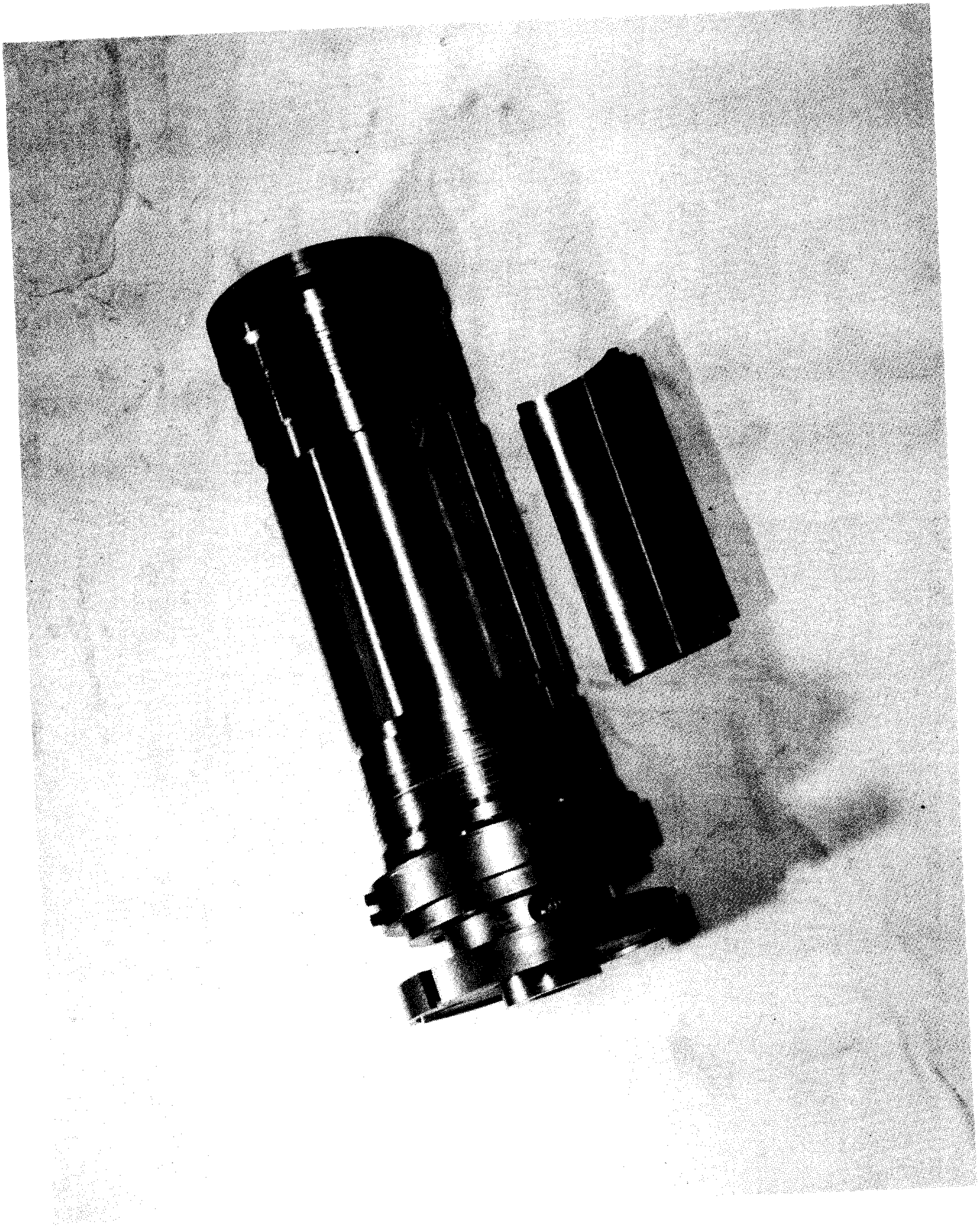
Adapter Clamped to Arbor

Figure 52



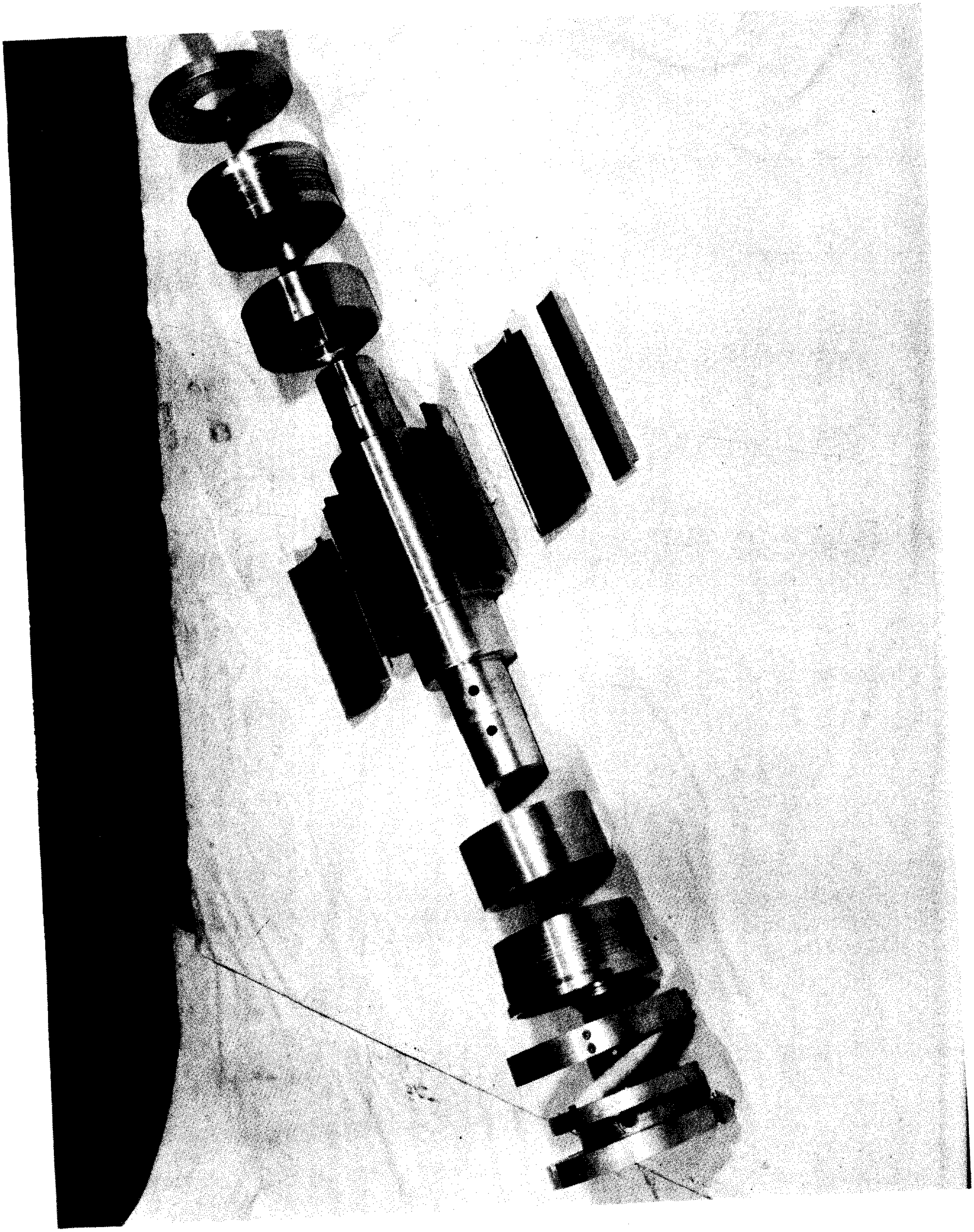
Support Tube

Figure 53.



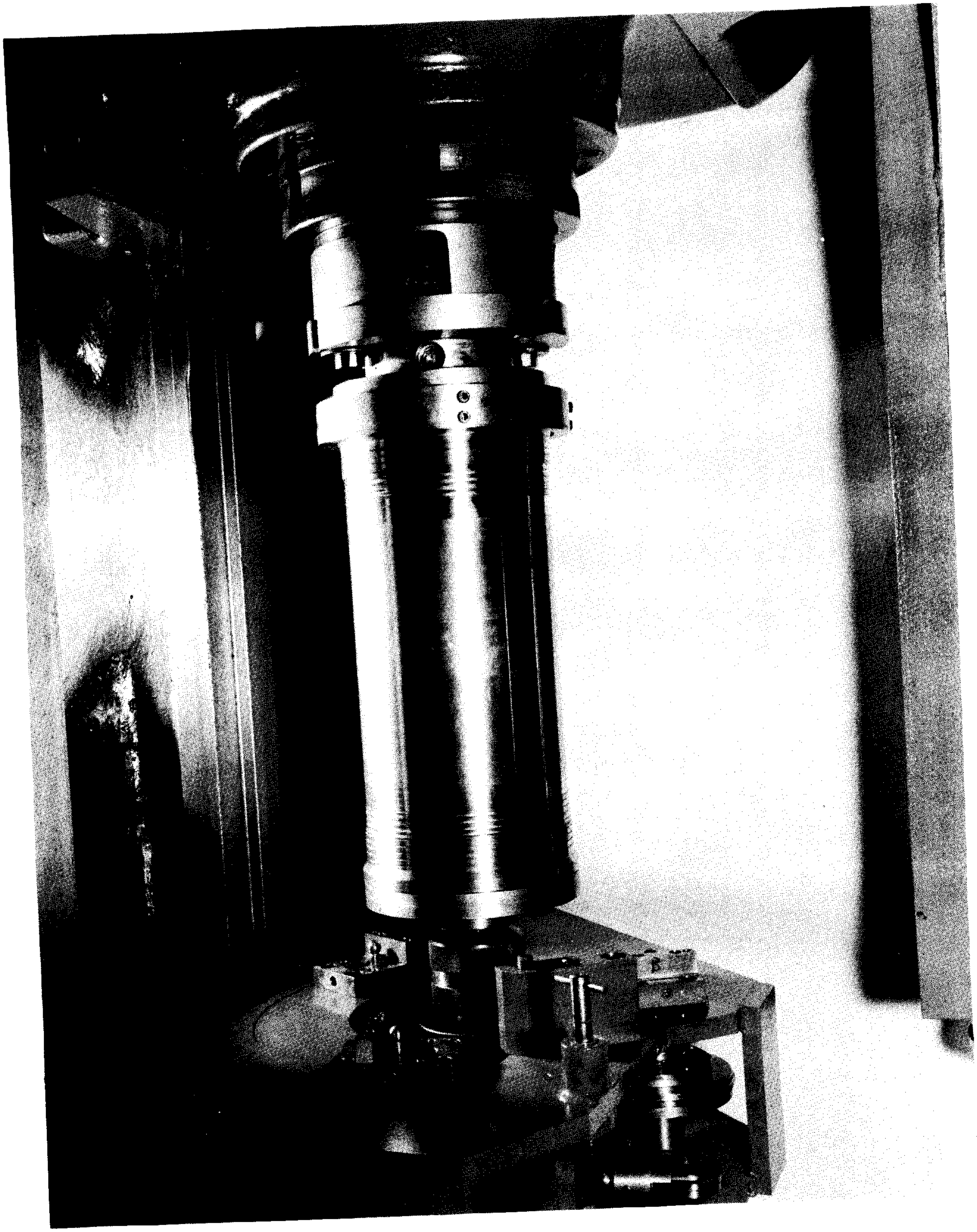
Mandrel Assembled

Figure 54



Exploded View of Mandrel

Figure 55

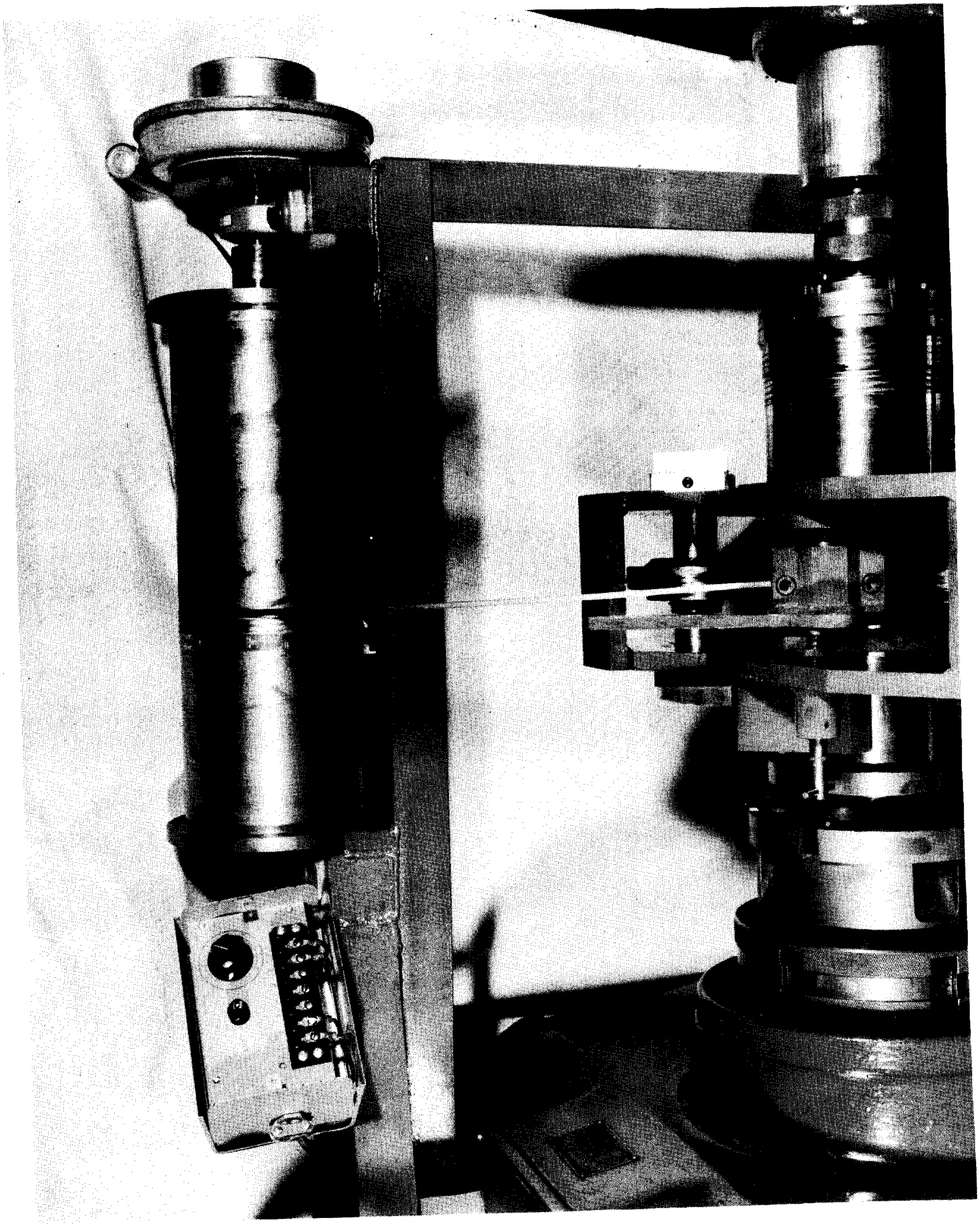


Mandrel Set on Lathe

Figure 56

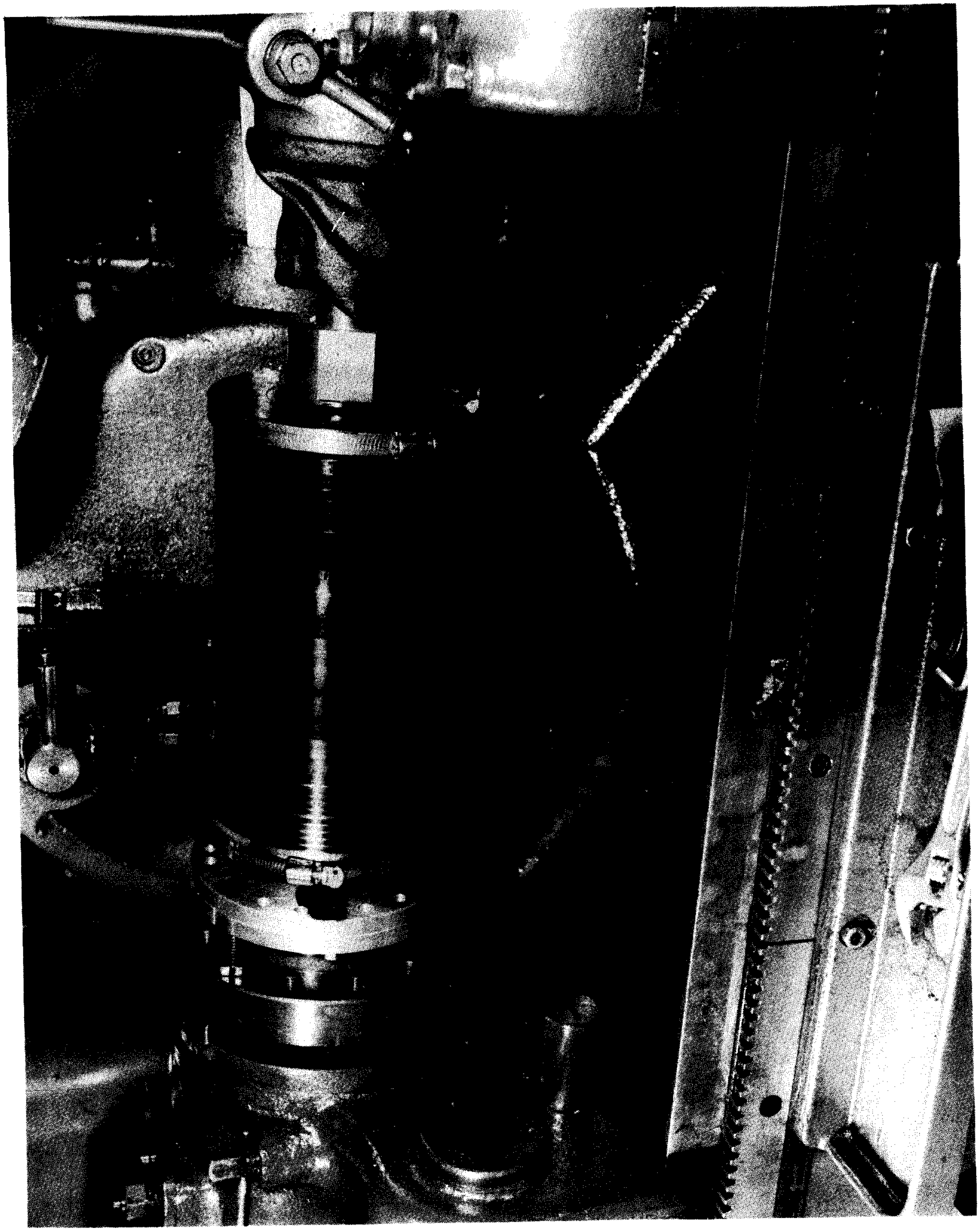
Reels

Figure 57



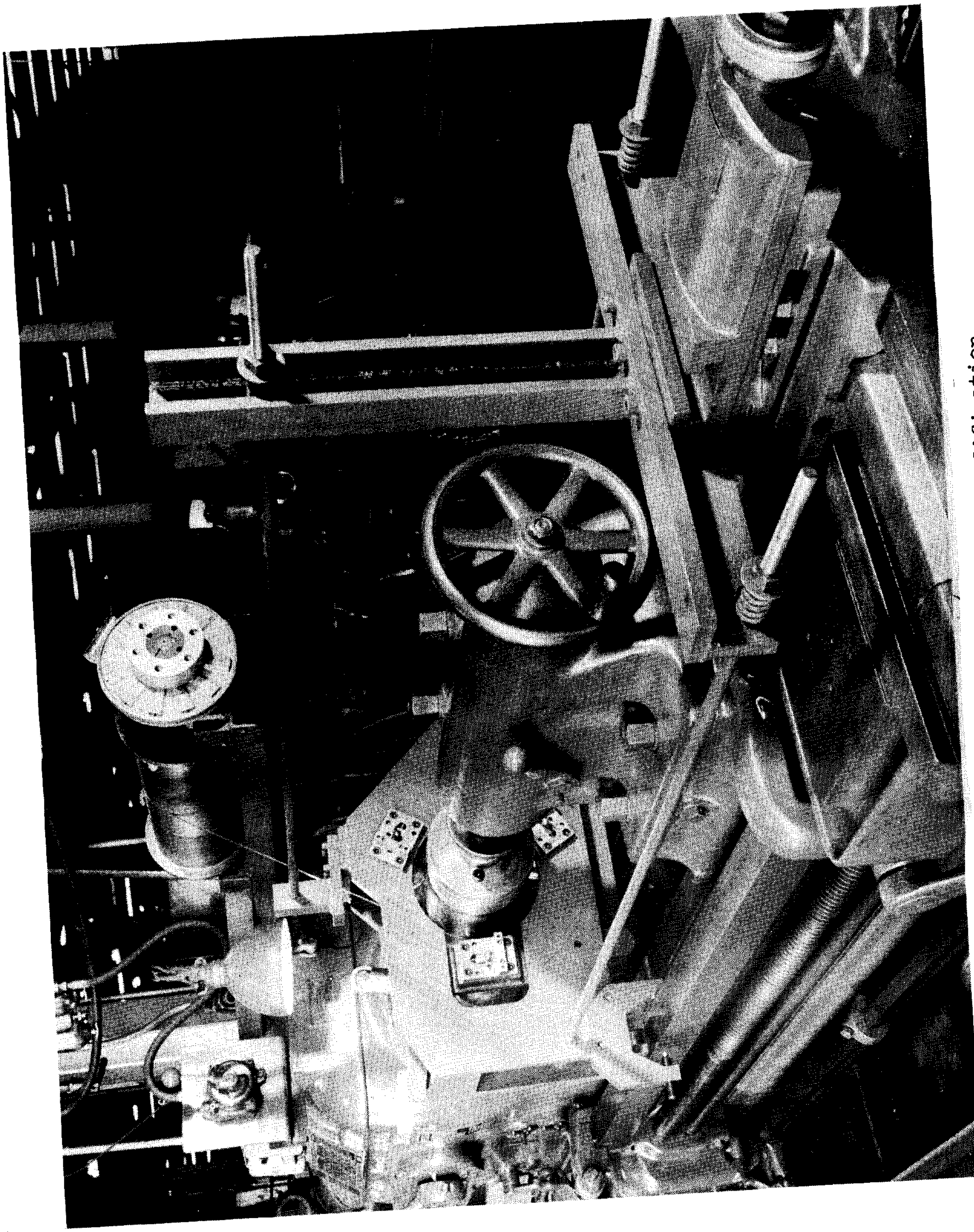
Drag Brake

Figure 58



Dummy Arbor

Figure 59



Wrapping Apparatus Modification

Figure 60

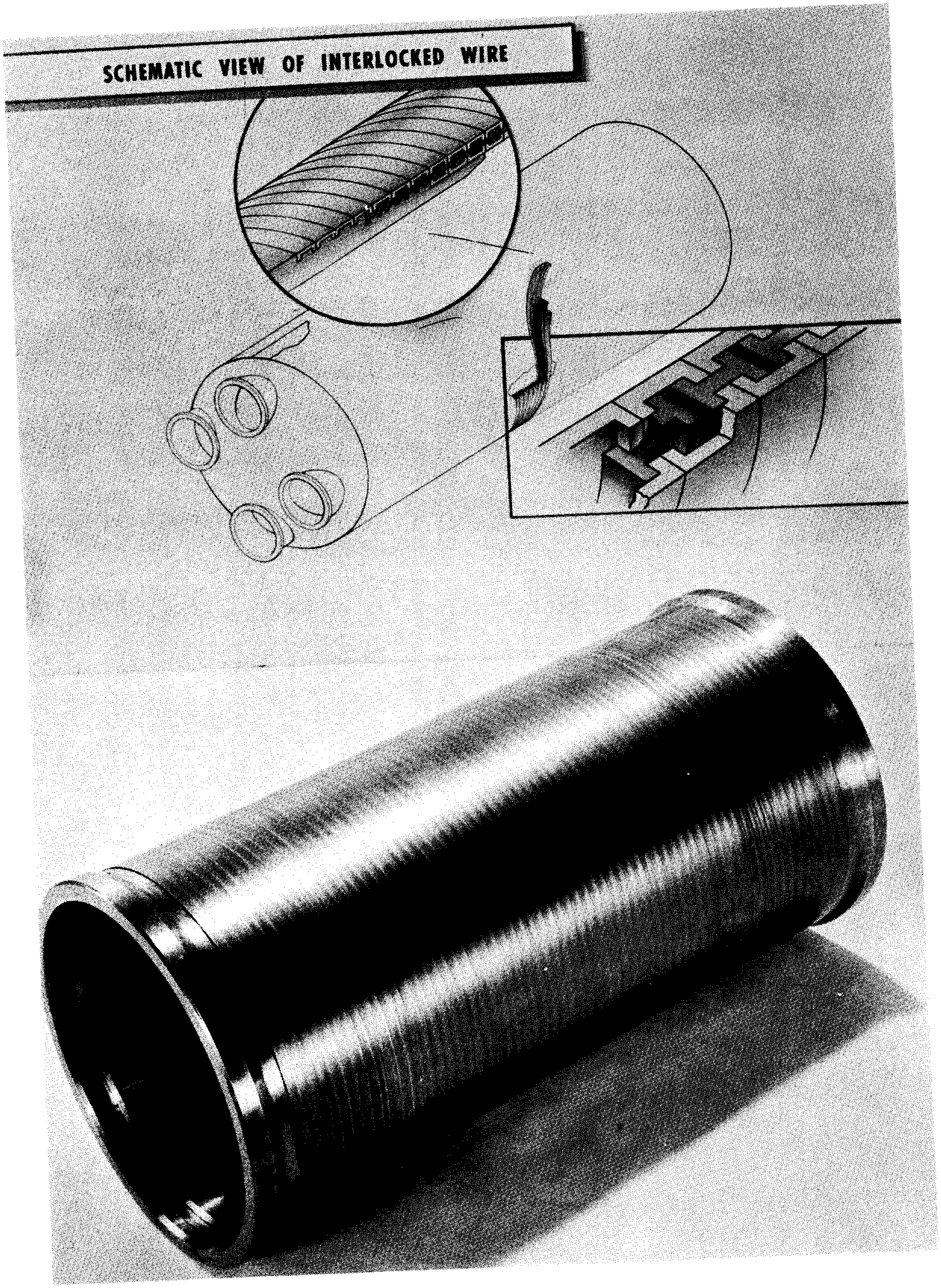
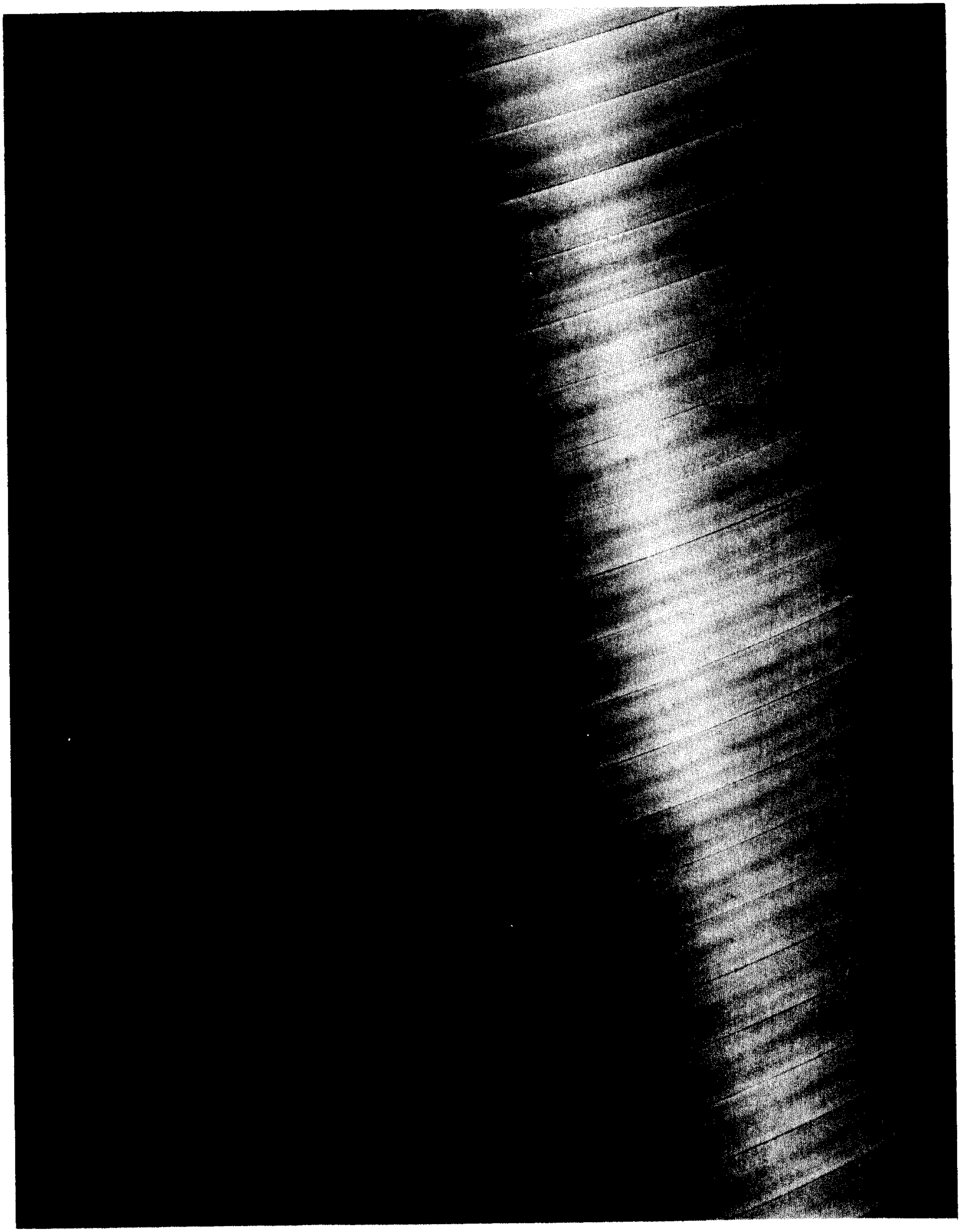


Figure 61



Wrap Vessel Specimen   Close-up

Figure 62

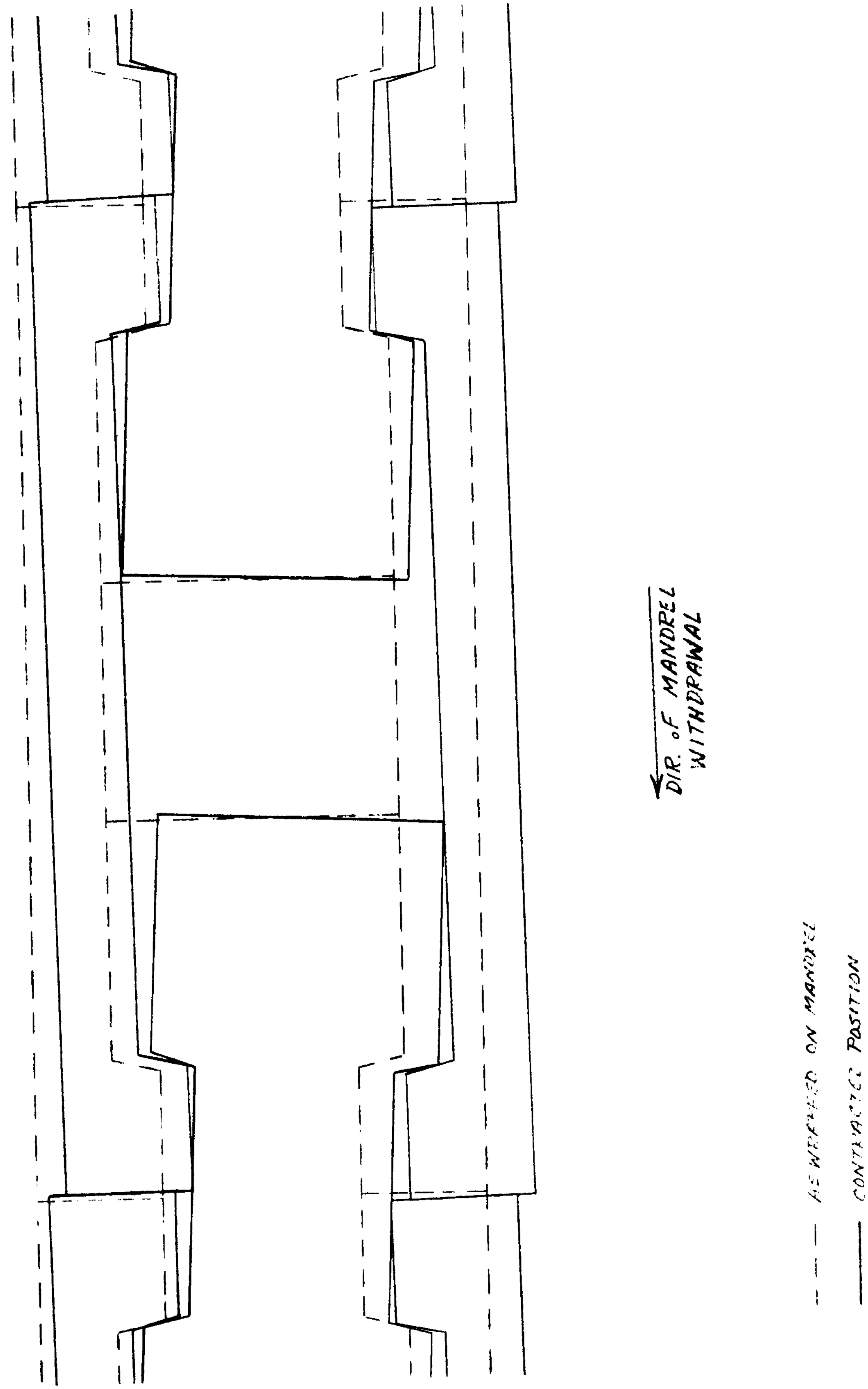

DIR. OF MANDREL WITHDRAWAL
AS WRAPPED ON MANDREL
CONTRACTED POSITION

Figure 63

APPENDIX I

STRESS ANALYSIS

CURTISS - WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET ____ OF SHEETS ____

WRITTEN BY L. SEELEN
APPROVED BY
DATE 7-18-60

ENGINE NO.
JOB NO. 51792
SUBJECT: INTERLOCKING WIRE WRAP VESSEL

RESULTS, SKETCHES & FORMULAS

APPENDIX A

STRESS ANALYSIS - CALCULATIONS

INTERLOCKING WIRE WRAP VESSEL

CURTISS - WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET a OF SHEETS 28

ENGINE NO.

JOB NO. 51792

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

WRITTEN BY L. SEELEN

APPROVED BY WBG

DATE 3-10-60

RESULTS, SKETCHES & FORMULAS

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CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 1 OF SHEETS 28

ENGINE NO.

JOB NO. 51792

SUBJECT:

WRITTEN BY L. SEELEN

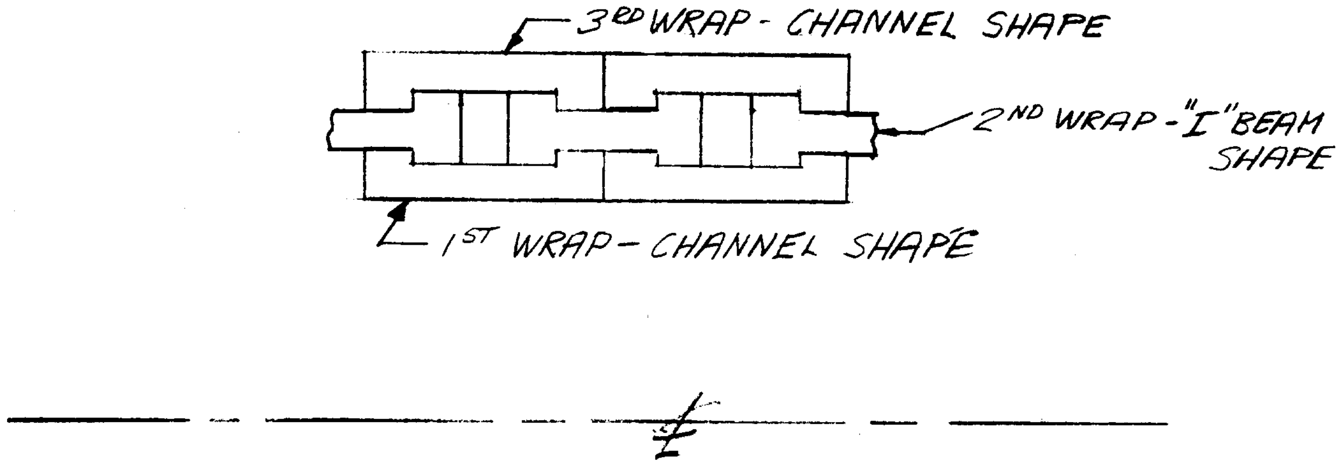
APPROVED BY WBG

DATE 10-19-59

INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

DESIRED CONFIGURATION



VESSEL DIAMETER —— 6.2"

DESIGN PRESSURE —— 5000 psi

MATERIAL

TITANIUM WIRE
B120 VCA

.2% YIELD STRESS
250000 psi (LONGITUDINAL & TRANSVERSE)

MODULUS OF ELASTICITY
15×10^6 psi

ALLOWABLE SHEAR STRESS = $.6 \times 250000 = 150000$ psi

ALLOWABLE BEARING STRESS = $\frac{1.5 \times 250000}{.9} = 416000$ psi

ENGINE NO.

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APPROVED BY WBG

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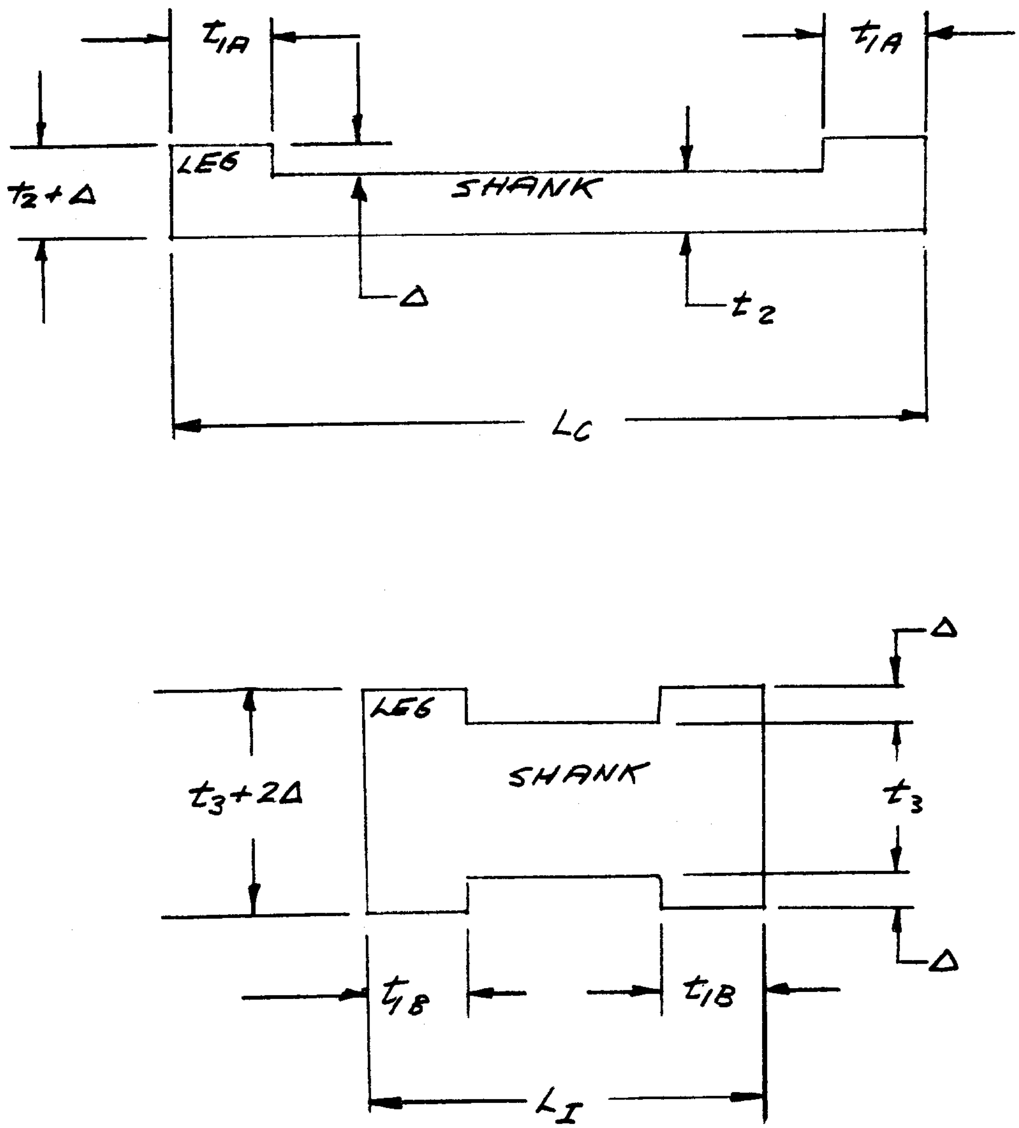
RESULTS, SKETCHES & FORMULAS

WIRE NOMENCLATURE



ENGINE NO.

JOB NO. 51792

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

WRITTEN BY L. SEELEN

APPROVED BY WBG

DATE 10-20-59

RESULTS, SKETCHES & FORMULAS

LOADING

$p = 5000 \text{ psi} \quad D = 6.2''$

CIRCUMFERENTIAL LOAD

$$= 5000 \frac{\#}{in^2} \times 3.1 in = 15500 \ \#/in$$

AXIAL LOAD

$$= \frac{5000 \ \#/in^2 \times 3.1 in}{2} = 7750 \ \#/in$$

BASIC DIMENSIONS - BASED ON AXIAL LOADS

CHANNEL SHAPE

$$2t_2 = \frac{7750}{250000}$$

$$t_2 = .0155 \text{ in}$$

$$2t_{1A} = \frac{7750}{150000}$$

$$t_{1A} = .02583$$

$$2\Delta = \frac{7750}{416000}$$

$$\Delta = .009315$$

DUMBELL SHAPE

$$t_3 = 2t_2$$

$$t_3 = .031 \text{ in}$$

$$t_{1B} = t_{1A}$$

$$t_{1B} = .02583$$

$$\Delta = .009315$$

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RESULTS, SKETCHES & FORMULAS

BASIC DIMENSIONS (CONT'D) - BASED ON CIRCUMFERENTIAL LOADS

THE AREA OF ONE PITCH MUST CARRY THE LOAD/PITCH

$$A_P = 2A_{CHANNEL} + A_{"I"}$$

PITCH LENGTH $= L_C$

$$AREA_{CHANNEL} = 2\, t_{1A} \Delta + t_2 L_C$$
$$= 2 \times .02583 \times .009315 + .0155\, L_C$$
$$= .0004812 + .0155\, L_C$$

$$AREA_{"I"\,SHAPE} = 4\, t_{1B} \Delta + t_3 L_{"I"}$$
$$= .0009624 + .031\, L_{"I"}$$

SETTING $L_C = .200$ in

$$A_C = .0004812 + .0031 = .0035812$$

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RECORD OF ANALYSIS

SHEET 5 OF SHEETS 28

WRITTEN BY L. SEELEN
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DATE 10-20-59

ENGINE NO.
JOB NO. S1792

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

BASIC DIMENSIONS (CONT'D)

$$.2 \times 15500 = 250000\,(.0035812 \times 2 + .0009624 + .0310\, L_{\text{"I"}})$$

$$\frac{3100}{250000} = .0081248 + .0310\, L_{\text{"I"}}$$

$$L_{\text{"I"}} = \frac{.0124 - .0081248}{.031} = \frac{.004275}{.031} = .1379 \text{ in}$$

HOWEVER

THE FIT OF THE CHANNEL LEGS IN THE "I" BEAM IS TO BE A 1 - 4% PRESS FIT

THEREFOR THE "I" BEAM SHANK MUST BE MADE HEAVIER TO TAKE THE PRELOAD

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WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 6 OF SHEETS 28

WRITTEN BY L. SEELEN

APPROVED BY WBG

DATE 10-20-59

ENGINE NO.

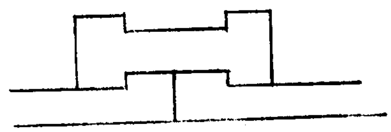
JOB NO. 51792

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

INCREASE t_3 TO .040

1- WRAPPING "I" BEAM LAYER ON 1ST CHANNEL LAYER



TOTAL DEFORMATION = 8 %

COMPRESSION OF CHANNEL LEGS $= \frac{.040}{.040+.0186} \times 8\% = 5.46\ \%$

ELONGATION OF "I" BEAM SHANK $= \frac{.0186}{.040+.0186} \times 8\% = 2.54\ \%$

2- WRAPPING 2ND CHANNEL LAYER ON "I" BEAM LAYER

SINCE THE "I" BEAM SHANK HAS ELONGATED 2.54 %
THE TOTAL DEFORMATION DURING THIS WRAP = 5.46 %

FURTHER ELONGATION OF "I" BEAM SHANK

$$= \frac{.0186}{.040+.0186} \times 5.46\% = 1.633\ \%$$

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RECORD OF ANALYSIS

SHEET 7 OF SHEETS 28

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APPROVED BY WBG

DATE 10-21-59

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

TOTAL ELONGATION OF "I" BEAM SHANK

$= (2.54 + 1.633)\% = 4.173\%$

THIS IS WITHIN THE ALLOWABLE VALUE, AND ENSURES AGAINST ANY LOSS OF PRELOAD DUE TO PRESSURIZATION SINCE THE PRESSURE LOAD NEVER EXCEEDS THE PRELOAD, THE CHANNEL LEGS REMAIN BUTTED, AND NEITHER THE CHANNEL LEGS NOR THE "I" BEAM LEGS ARE SUBJECT TO BENDING STRESSES.

<u>RE-SIZE "I" BEAM</u>

ALL DIMENSIONS EXCEPT L_I REMAIN

$$L_I = \frac{.031}{.040} \times .1379 = .1069 \text{ in}$$

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WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 8 OF SHEETS 28

WRITTEN BY L SEELEN
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DATE 10-21-59

ENGINE NO.
JOB NO. S1792

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

FINAL SIZE

CHANNEL

$t_2 = .0155$

$t_{1A} = .026$

$\Delta = .0093$

$L_C = .200$

"I" BEAM

$t_3 = .040$

$t_{1B} = .026$ *

$\Delta = .0093$

$L_I = .1069$

* SEE PP10 & 15, CASE 1B, FOR SUGGESTED INCREASE TO .040 in.

WRITTEN BY L-SEELEN
APPROVED BY WBG
DATE 10-21-59

ENGINE NO.
JOB NO. 51792
SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

IF THE "I" BEAM SHAPE DOES NOT BOTTOM ON CHANNEL WRAP THE SPAN IS .1472 IN. THE DEFLECTION OF THE CHANNEL .025 IN FROM THE END

$$= \frac{5000 \times .025^2 (.1472 - .025)^2 \times 12}{24 \times 15 \times 10^6 \times .0155^3} = .000417 \text{ IN.}$$

IF THE "I" BEAM LEG HEIGHTS ARE MIN
AND THE CHANNEL LEG HEIGHTS ARE MAX
THE CLEARANCE IS .0004 IN.

DEFORMATION DUE TO THE PRESS FIT CAUSES THE CLEARANCE TO APPROACH ZERO, AND THE ANALYSIS ASSUMING THE DISTANCE BETWEEN "I" BEAMS AS THE CHANNEL SPAN IS ESSENTIALLY CORRECT

A MORE ACCURATE METHOD ASSUMES A FIXED BEAM WITH THE .1472" SPAN LENGTH SIMPLY SUPPORTED .025" FROM EITHER END.

CURTISS - WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 10 OF SHEETS 28

ENGINE NO.

JOB NO. 51792

WRITTEN BY L. SEELEN

APPROVED BY WBG

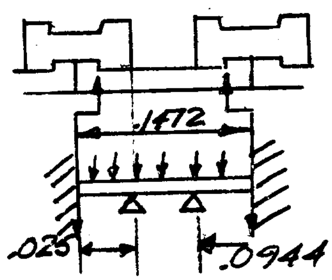
DATE 10-21-59

SUBJECT: INTERLOCKING WIRE WRAP VESSEL

RESULTS, SKETCHES & FORMULAS

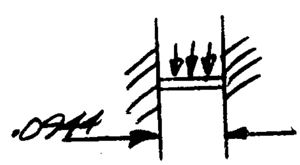
ASSUMED CONFIGURATIONS

CASE 1A — FIXED ENDED - SIMPLY SUPPORTED AT "I" BEAM ENDS



CASE 1B - SAME AS 1A EXCEPT .025 = .040

CASE 2A, 2B FIXED ENDED AT "I" BEAM ENDS



ENGINE NO.

JOB NO. 51792

WRITTEN BY L. SEELEN

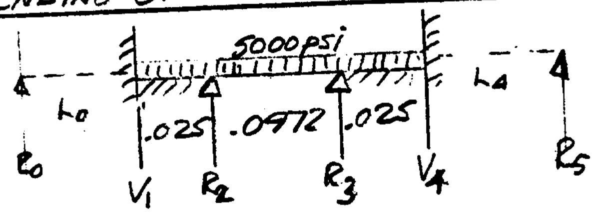
APPROVED BY WBG

DATE 10-22-59

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

BENDING OF 1ST CHANNEL WRAP UNDER PRESSURE - CASE 1a



THREE MOMENT METHOD

SPAN 0-1

$$① \quad M_0L_0 + 2M_1(L_0+L_1) + M_2L_1 + \frac{6A_0\bar{a}_0}{L_0} + \frac{6A_1\bar{b}_1}{L_1} = 0$$

SPAN 1-2

$$② \quad M_1L_1 + 2M_2(L_1+L_2) + M_3L_2 + \frac{6A_1\bar{a}_1}{L_1} + \frac{6A_2\bar{b}_2}{L_2} = 0$$

SPAN 2-3

$$③ \quad M_2L_2 + 2M_3(L_2+L_3) + M_4L_3 + \frac{6A_2\bar{a}_2}{L_2} + \frac{6A_3\bar{b}_3}{L_3} = 0$$

SPAN 3-4

$$④ \quad M_3L_3 + 2M_4(L_3+L_4) + M_5L_4 + \frac{6A_3\bar{a}_3}{L_3} + \frac{6A_4\bar{b}_4}{L_4} = 0$$

IN APPLYING THESE EQUATION ALL TERMS REFERRING TO THE IMAGINARY SPANS ARE NEGLECTED.

SINGER - STRENGTH OF MATERIALS

CURTISS - WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 12 OF SHEETS 28

WRITTEN BY L. SEELEN
APPROVED BY WBG
DATE 10-22-59

ENGINE NO.
JOB NO. 51792
SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

$$6\frac{A_1\bar{b}_1}{L_1} = 5000 \times \frac{\overline{.025}^3}{4} = .01954$$

$$6\frac{A_1\bar{a}_1}{L_1} = 5000 \times \frac{\overline{.025}^3}{4} = .01954$$

$$6\frac{A_2\bar{b}_2}{L_2} = 5000 \times \frac{\overline{.0972}^3}{4} = 1.1479$$

$$6\frac{A_2\bar{a}_2}{L_2} = 5000 \times \frac{\overline{.0972}^3}{4} = 1.1479$$

$$6\frac{A_3\bar{b}_3}{L_3} = 5000 \times \frac{\overline{.025}^3}{4} = .01954$$

$$6\frac{A_3\bar{a}_3}{L_3} = 5000 \times \frac{\overline{.025}^3}{4} = .01954$$

① $2M_1(.025) + M_2(.025) + .01954 = 0$

② $M_1(.025) + 2M_2(.1222) + M_3(.0972) + .01954 + 1.1479 = 0$ .0195

③ $M_2(.0972) + 2M_3(.1222) + M_4(.025) + .01954 + 1.1479 = 0$

④ $M_3(.025) + 2M_4(.025) + .01954 = 0$

① $.050\,M_1 + .025\,M_2 + .01954 = 0$

② $.025\,M_1 + .2444\,M_2 + .0972\,M_3 + 1.16744 = 0$

③ $.0972\,M_2 + .2444\,M_3 + .025\,M_4 + 1.16744 = 0$

④ $.025\,M_3 + .05\,M_4 + .01954 = 0$

CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 13 OF SHEETS 28

ENGINE NO.

JOB NO. 51792

WRITTEN BY L. SEELEN

APPROVED BY WBG

DATE 10-22-59

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

		M_1	M_2	M_3	M_4	K
1		.050	.025			-.01954
2	$\frac{.025}{.050} = .5$	.025	.2444	.0972		-1.16744
3	-.5×1	-.025	-.0125			+.00977
4	2+3	0	.2319	.0972		-1.15767
5			.0972	.2224	.025	-1.16744
6		-	-	-	-	-
7	5+6 $\frac{.0972}{.2319} = .4192$		.0972	.2444	.025	-1.16744
8	-.4192×4		-.0972	-.0407	-	+.48530
9	7+8		0	.2037	.025	-.68214
10				.025	.050	-.01954
11		-	-	-	-	-
12	10+11			.025	.050	-.01954
13		-	-	-	-	-
14	12+13 $\frac{.025}{.1816} = .1377$			.025	.050	-.01954
15	-.1377×9			-.025	-.00344	+.09382
16				0	.04656	.07428

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WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 14 OF SHEETS 28

WRITTEN BY L. SEELEN
APPROVED BY WBG
DATE 10-22-59

ENGINE NO.
JOB NO. 51792
SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

$M_4 = .07428 / .04656 = +1.5954$

$$M_3 = \frac{-.68214 - .025 \times 1.5954}{.2037} = -3.5446$$

$$M_2 = \frac{-1.15767 + .0972(3.5446)}{.2319} = -3.5064$$

$$M_1 = \frac{-.01954 + .025(3.5064)}{.050} = +1.3624$$

HOWEVER M_1 SHOULD EQUAL M_4 AND $M_2 = M_3$
THE DISCREPANCY IS DUE TO THE NUMBER OF CALCULATIONS PERFORMED

ASSUME

$$M_1 = M_4 = \frac{1.5954 + 1.3624}{2} = 1.4788 \quad \text{in-lb/in}$$

$$M_2 = M_3 = \frac{-(3.5064 + 3.5446)}{2} = -3.5255 \quad \text{in-lb/in}$$

$S_{b_1} = 6 \times 1.4788 / .0155^2 = \underline{36900}$

$S_{b_2} = 6 \times 3.5255 / .0155^2 = \underline{88000}$

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WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

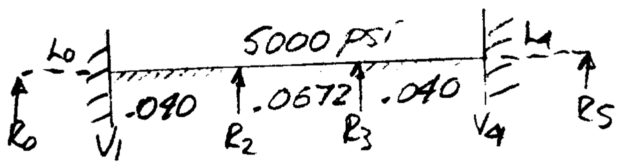
SHEET 15 OF SHEETS 28

WRITTEN BY L. SEELEN
APPROVED BY WBG
DATE 10-23-59

ENGINE NO.
JOB NO. 51792
SUBJECT: INTERLOCKING WIRE WRAPPED MOTOR

RESULTS, SKETCHES & FORMULAS

BENDING OF 1ST CHANNEL WRAP UNDER PRESSURE - CASE 1b



$$\frac{5000 \times .040^3}{4} = .03 \qquad .03 + .3793 = .4093$$

$$\frac{5000 \times .0672^3}{4} = .3793$$

① $.080 M_1 + .040 M_2 = -.03$

② $.040 M_1 + .2144 M_2 + .0672 M_3 = -.4093$

BY SYMMETRY $M_2 = M_3$

① $.080 M_1 + .040 M_2 = -.03$

② $.040 M_1 + .2816 M_2 = -.4093$

1/2 ③ $.040 M_1 + .0200 M_2 = -.0150$

③ $0 \qquad .2616 M_2 = -.3943$

$$M_2 = -\underline{1.507}$$

$$M_1 = \frac{-.03 + .04 \times 1.507}{.08} = \underline{.3785}$$

$$S_{b_1} = \frac{6 \times .3785}{.0155^2} = 9440 \text{ psi}$$

$$S_{b_2} = \frac{6 \times 1.507}{.0155^2} = 37600 \text{ psi}$$

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RECORD OF ANALYSIS

SHEET 16 OF SHEETS 28

ENGINE NO.

JOB NO. 51792

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

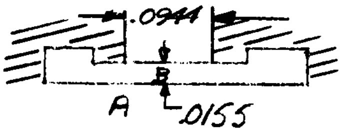
WRITTEN BY L. SEELEN

APPROVED BY W.B.

DATE 10-23-59

RESULTS, SKETCHES & FORMULAS

BENDING OF 1ST CHANNEL WRAP DUE TO PRESSURE - CASE 2 a



TREATING THE CHANNEL AS A FIXED ENDED BEAM WHERE "A" IS AT THE SUPPORT AND "B" IS AT THE CENTER.

$$M_{"A"} = p\frac{(.0944)^2}{12} = .0007426\,p \qquad Z = \frac{1 \times .0155^2}{6} = .4 \times 10^{-4}$$

$$M_{"B"} = p\frac{(.0944)^2}{24} = .0003713\,p$$

$$S_{b\,"A"} = .0007426\,p / .00004 = 18.565\,p = \underline{93000 \text{ psi}}$$

$$S_{b\,"B"} = .0003713\,p / .00004 = 9.283\,p = \underline{46500 \text{ psi}}$$

WITH A SUBSCALE VESSEL SUCH AS THE ONE CURRENTLY UNDER DEVELOPMENT, THE BENDING STRESSES IN THE 1ST CHANNEL WRAP WILL BE LARGE.

HOWEVER FULL SCALE VESSELS OPERATE AT SUBSTANTIALLY LOWER PRESSURES AND THIS STRESS IS NEGLIGIBLE.

THE CHANGE IN "I" BEAM WIDTH SUGGESTED ON PAGE 15 WILL REDUCE THESE STRESS TO 43000 psi AT THE END AND 21600 psi AT THE CENTER (CASE 2B)

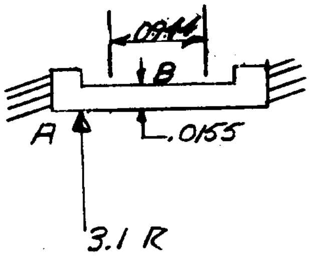
ENGINE NO.
JOB NO. 51792

WRITTEN BY L. SEELEN
APPROVED BY WB
DATE 10-23-59

SUBJECT: INTERLOCKING WIRE WRAPPED VESSEL

RESULTS, SKETCHES & FORMULAS

BENDING OF 1ST CHANNEL WRAP UNDER PRESSURE - CASE 3



FIXED ENDED BEAM ON ELASTIC FOUNDATION

$$\lambda = 1.285 / \sqrt{3.1 \times .0155} = 5.868$$

$$\lambda L = 5.868 \times .0944 = .55$$

$$\lambda^2 = 34.433$$

$$M_A = \frac{-P}{2\lambda^2}\left[\frac{\sinh \lambda L - \sin \lambda L}{\sinh \lambda L + \sin \lambda L}\right]$$ MOMENT AT ENDS $.2 - \frac{.0264}{\frac{4}{.1056}} = .0944$

$$M_B = \frac{P}{\lambda^2}\left[\frac{\sin \frac{\lambda L}{2} \cosh \frac{\lambda L}{2} - \cos \frac{\lambda L}{2} \sinh \frac{\lambda L}{2}}{\sinh \lambda L + \sin \lambda L}\right]$$ MOMENT AT CENTER

for $\lambda L = .55$

$$M_A = \frac{-5000}{2 \times 34.333}\left\{\frac{.5782 - .5227}{.5782 + .5227}\right\} = -3.67 \text{ in-lb/in}$$

$$M_B = \frac{-5000}{34.333}\left\{\frac{.2764 \times 1.0395 - .9611 \times .2837}{1.1009}\right\} = 1.93 \text{ in-lb/in}$$

$$\sigma_{M_A} = \frac{6 \times -3.67}{.0155^2} = 91660 \text{ psi}$$

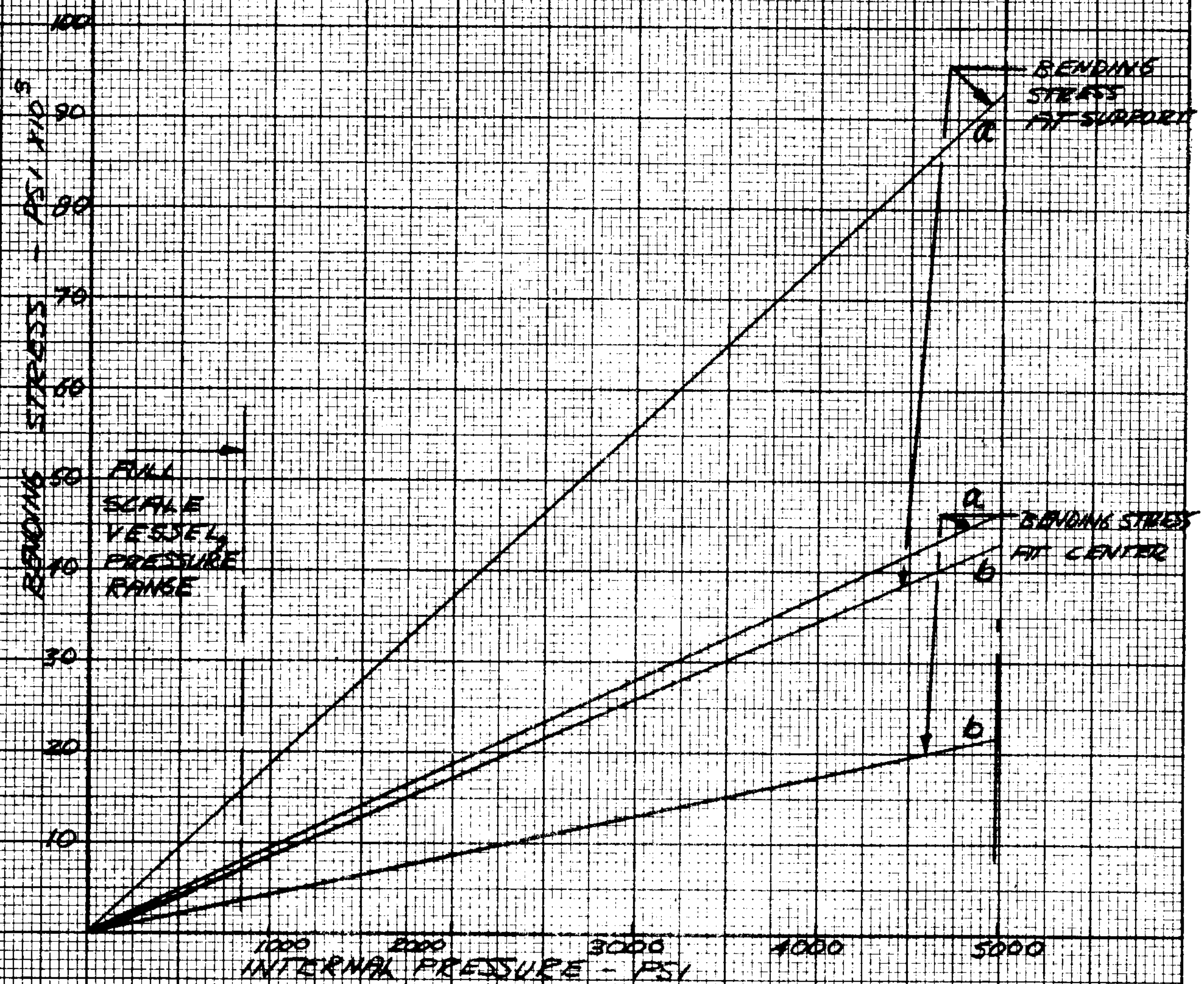
$$\sigma_{M_B} = 48200 \text{ psi}$$

NOTE: COMPARISON OF THESE STRESSES WITH THOSE OF CASE 2b SHOWS A NEGLIGIBLE REDUCTION IN BENDING STRESS RESULTING FROM CONSIDERATION OF VESSEL CURVATURE

M. Hetenyi - Beams on Elastic Foundations

INTERLOCKING WIRE WRAPPED VESSEL
(6 IN. SUBSCALE)

BENDING OF 1ST CHANNEL WRAP - CASE 2a & 2b



A. SEELEN

10/23/59
WBG

CURTISS - WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 19 OF SHEETS 28

ENGINE NO. Wire Wrap Motor

JOB NO. 51792

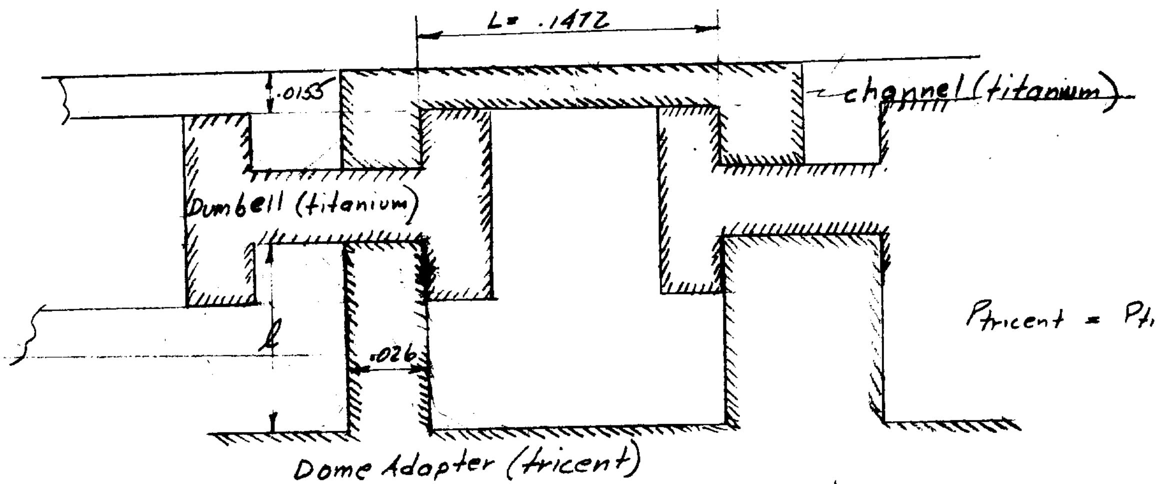
SUBJECT: Dome Adapter stresses

WRITTEN BY D. Kanowsky

APPROVED BY WBG

DATE 2/19/60

RESULTS, SKETCHES & FORMULAS



$P_{tricent} = P_{titanium}$

$$\Sigma \delta_{tr} = \delta_c$$

$$\left(\frac{P\ell^3}{3EI} + \frac{6}{5}\frac{P\ell}{AG}\right)_{tr} = \left(\frac{PL}{AE}\right)_c$$

	titanium	tricent
A	.0155	.026
E	16×10^6	30×10^6
G		12×10^6
ℓ	.1472	?
I		$\frac{1}{12}(.025)^3 = 1.30 \times 10^{-6}$

$$\frac{\ell^3}{3(30)(1.30)} + \frac{6}{5}\frac{\ell}{(.026)(12\times10^6)} = \frac{.1472}{(.0155)(16\times10^6)}$$

$$.00854\ell^3 + 3.85\times10^{-6}\ell = .594\times10^{-6}$$

$$\ell^3 + 4.51\times10^{-4}\ell = .697\times10^{-4}$$

$$\ell = .037 \quad (\text{Say } .035'')$$

$P_{total} = 7750\ \#/in \qquad P_{tr} = P_c = 3875\ \#$

tricent: $M = 3875 \times .035 = 136$

$$\frac{I}{c} = \frac{1.30\times10^{-6}}{1.3\times10^{-2}} = 1\times10^{-4}$$

$$\sigma = \frac{136}{1}\times10^4 = \text{HIGH}$$

shear

$$\sigma = \frac{V}{A} = \frac{3875}{.026} = 149{,}000\ psi$$

If tricent is assumed to be prevented from bending, by the abutting channel:

then: $3.85\ell = .594$

$\therefore \ell = .155''$

CURTISS-WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 20 OF SHEETS 28

ENGINE NO. Wire Wrap Motor

JOB NO. 51792

SUBJECT: Trial & Error solution for "l"

WRITTEN BY D. Kanowsky

APPROVED BY WBG

DATE 2/19/60

RESULTS, SKETCHES & FORMULAS

$$l^3 + 4.51\times10^{-4}\, l = .697\times10^{-4}$$

l	.02	.03	.04	.035	.037	.038
l^3	$.08\times10^{-4}$	$.27\times10^{-4}$	$.64\times10^{-4}$	$.43\times10^{-4}$	$.507\times10^{-4}$	$.549\times10^{-4}$
$+4.51\,l\times10^{-4}$	$.090\times10^{-4}$	$.135\times10^{-4}$	$.1804\times10^{-4}$	$.158\times10^{-4}$	$.167\times10^{-4}$	$.171\times10^{-4}$
$=.697\times10^{-4}$	$.17\times10^{-4}$	$.405\times10^{-4}$	$.82\times10^{-4}$	$.588\times10^{-4}$	$.674\times10^{-4}$	$.720\times10^{-4}$

$$l = .037$$

RECORD OF ANALYSIS

WRITTEN BY D. Kanowsky
APPROVED BY WBG
DATE 2/19/60

ENGINE NO. Wire Wrap Motor
JOB NO. 51792
SUBJECT: Dome Adapter stress

RESULTS, SKETCHES & FORMULAS

$l = .035$:

Tolerance condition when tricent is stiffest:

	titanium	tricent
A	.0145	.0268
E	16×10^6	30×10^6
G		12×10^6
l	.15	.035
I		$\frac{1}{12}(.0268)^3 = 1.61\times10^{-6}$

$$P_{Tr}\left[\frac{(.035)^3}{3(30)(1.61)} + \frac{6}{5}\frac{.035}{(.0268)(12\times10^6)}\right] = P_c\left(\frac{.15}{(.0145)(16\times10^6)}\right)$$

$$P_{Tr}\left[.297\times10^{-6} + .130\times10^{-6}\right] = P_c\left(.648\times10^{-6}\right)$$

$$P_{Tr}(.427) = P_c(.648)$$

$$P_{Tr} = 1.52\,P_c$$

total $P = 7750^{\#}$ $\quad P_{Tr} = 4670^{\#}$

$P_c = 3080^{\#}$

Tricent: $\frac{I}{C} = \frac{1.61\times10^{-6}}{1.34\times10^{-2}} = 1.2\times10^{-4}$

$M = 4670\times.035 = 163$

$\sigma = \frac{163}{1.2}\times10^4 = \text{High}$

Shear $\sigma = \frac{4670}{.0268} = 174{,}000$ psi

Titanium: $S = \frac{P}{A} = \frac{3080}{.0145} = 210{,}000$

$\epsilon = \frac{S}{E} = \frac{210000}{16\times10^6} = \frac{.21}{16} = .013$

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WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 24 OF SHEETS 28

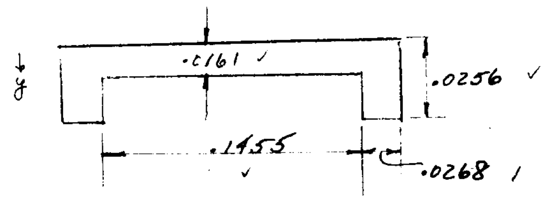
WRITTEN BY D. Kanowsky
APPROVED BY W.B.G.
DATE 2/18/60

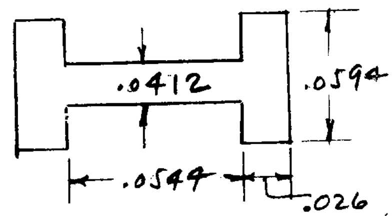
ENGINE NO.
JOB NO. S1792
SUBJECT: Wire Wrapped Motor
stress in wire on spool.

RESULTS, SKETCHES & FORMULAS

Wire to be unwrapped from 6" spool:

Bending stress:





$$\frac{M}{EI} = \frac{1}{R}$$

$$M = \sigma \rho' = \sigma \, I/c \qquad \sigma \doteq \frac{cE}{R} \ ✓$$

$$\frac{\sigma \, I/c}{EI} = \frac{1}{R}$$

channel:

$E = 16 \times 10^6$ psi

$R = 3.1''$

	A	y	Ay
	$.0161 \times .1455 = .00234$ ✓	$.0080$ ✓	$.0000187$ ✓
	$2 \times .0256 \times .0268 = .00137$ ✓	$.0128$ ✓	$.0000175$
	$.00371$		$.0000362$

$$\bar{y} = \frac{.0000362}{.00371}$$

$\bar{y} = c_1 = .00974$ ✓

$c_2 = .0256 - .00974$

$c_2 = .0159$ ✓

$$\sigma = \frac{(.0159)\,16 \times 10^6}{3.1}$$

$\sigma = 82{,}000$ psi

<u>NG</u> reduce to 50,000 psi <u>max</u> ✓

$$\sigma = (50{,}000) = \frac{(.0159)\,16 \times 10^6}{R} \ ✓$$

$$\min.\ R = \frac{(.0159)\,16 \times 10^6}{50 \times 10^3} = 5.05'' \ ✓$$

10.1" spool ✓

Dumbell.

$c_1 = c_2 = .0297''$ ✓

$$\sigma = \frac{.0297}{.0159} \times 82000 = 153{,}000 \text{ psi}$$

$$\min R \text{ for } 50{,}000 \text{ psi} = \frac{.0297}{.0159} \times 5.05 = 9.43''$$

<u>use 19" spool</u> ✓

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WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 28 OF SHEETS 28

ENGINE NO.

JOB NO. 51792

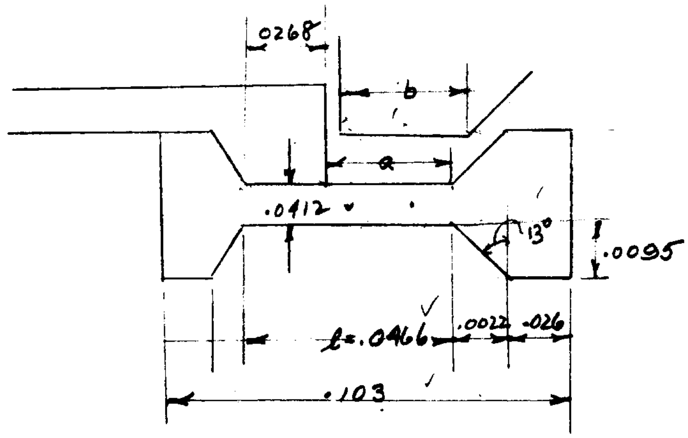
SUBJECT: Wire Wrapped Motor
Force req'd to place wire

WRITTEN BY D. Kanowsky

APPROVED BY WBG

DATE 2/18/60

RESULTS, SKETCHES & FORMULAS



$.0095 \tan 13° = .0095(.231)$
$= .0022$

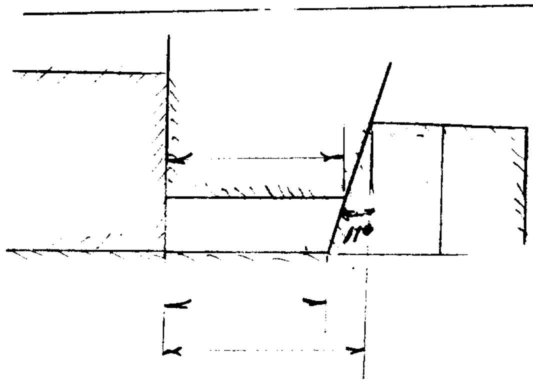
based on worst tolerance condition:

$$
\begin{array}{rl}
 & .103 \\
- & .052 = 2 \times .026 \\
\hline
 & .051 \\
- & .0044 = 2 \times .002 \\
\hline
\ell = & .0466 \\
- & .0268 \\
\hline
 & .0198 = a
\end{array}
\qquad
\begin{array}{rl}
b = & .0268 \\
a = & .0198 \\
\hline
\delta = & .0070''
\end{array}
$$

$$\delta = \frac{P\ell}{AE} \qquad P = \frac{AE\delta}{\ell}$$

[Horizontal Force] $P = \dfrac{(.0412)(16 \times 10^6)(.007)}{.0466} = 98{,}800\#$

if deformation of other parts are considered, P will be reduced by about 60%. Assume P = 40,000#



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WRIGHT AERONAUTICAL DIVISION

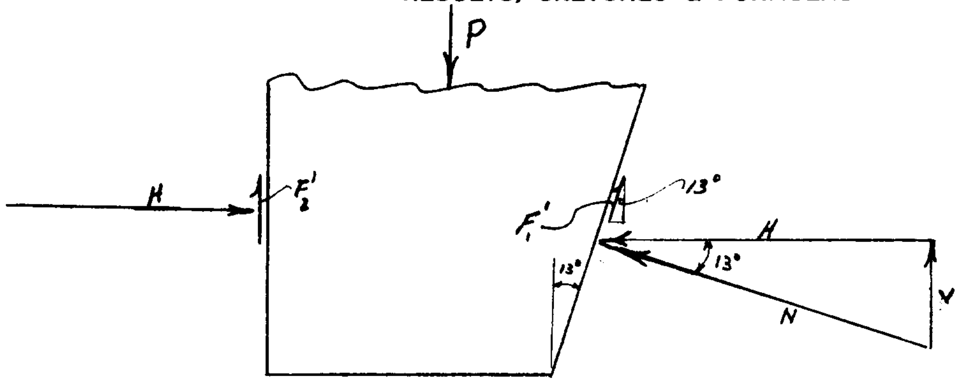
RECORD OF ANALYSIS

SHEET 24 OF SHEETS 28

ENGINE NO. Wire Wrap
JOB NO. 51792
SUBJECT: Force req'd to place wire

WRITTEN BY D. Kanowsky
APPROVED BY W.B.G.
DATE 2/23/60

RESULTS, SKETCHES & FORMULAS



$$P = H \tan 13° + F_1' \cos 13° + F_2'$$

$$F_1' = \mu N = \mu \frac{H}{\cos 13°}$$

$$F_2' = \mu H$$

$$P = H\left[\tan 13° + 2\mu\right]$$

$H = 40{,}000^{\#}$ per inch circumference

$\mu = .2$ (assumed)

$\tan 13° = .231$

$\tan 13° = .231$

$2\mu = \underline{.400}$

$.631 \times 40{,}000$

$P \doteq 25{,}000^{\#}$/inch of circum.

assume length of contact between roller & wire = .1"

$P = .1 \times 25000$

apply $\underline{\underline{P = 2500^{\#}}}$

RECORD OF ANALYSIS

ENGINE NO. Wire Wrap

JOB NO. 51792

SUBJECT: Axial Pull for Wrapping wire

WRITTEN BY D. Kanowsky

APPROVED BY WBG

DATE 3/8/60

RESULTS, SKETCHES & FORMULAS

Spool Diameter 7"

Vessel Diameter 6.5"

$$\frac{M}{EI} = \frac{1}{R}$$

$$\sigma_b = \frac{Mc}{I} = \frac{EI}{R} \cdot \frac{c}{I} = \frac{Ec}{R}$$

Hold σ to $.70\,\sigma_y = .70 \times 250,000 = 175,000$ psi

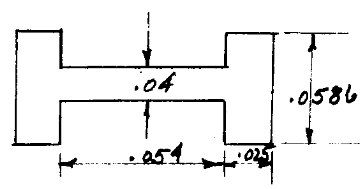
$$\sigma = \sigma_b + \sigma_a$$

$$\sigma = \frac{Ec}{R} + \frac{P}{A} \leq 175,000$$

Dumbell

$c = .0297"$

$A = .00509\,\square"$



Area: $.04 \times .054 = .00216$

$+ 2 \times .025 \times .0586 = .00293$

$A = .00509$

unwinding: $\frac{Ec}{R} = \frac{16 \times 10^6 \times .0297}{3.5} = 135{,}500$ psi

$$\frac{P}{A} = 175{,}000 - 135{,}500 = 39{,}500 \text{ psi}$$

$$P \leq 39{,}500 \times .00509$$

$$\underline{P \leq 201^{\#}}$$

channel

max $c = .016"$

$A = .0037\,\square"$

$$\frac{Ec}{R} = \sigma_b = \frac{.016}{.0297} \times 135{,}500 = 73{,}000 \text{ psi}$$

$$\frac{P}{A} = 175{,}000 - 73{,}000 = 102{,}000 \text{ psi}$$

$$P \leq 102{,}000 \times .0037$$

$$\underline{P \leq 377^{\#}}$$

ENGINE NO. Wire Wrap

JOB NO. 51792

SUBJECT: Axial Pull for Wrapping wire

WRITTEN BY D. Konowsky

APPROVED BY WBG

DATE 3/17/60

RESULTS, SKETCHES & FORMULAS

unwrapping wire from 7" spool:

Dumbell $\sigma = 135{,}500$ psi

channell $\sigma = 73{,}000$ psi

wire to be rewound on 6.5" diameter vessel

Dumbell:

$$\sigma' = \frac{Ec}{R} = \frac{16 \times 10^6 \times .0297}{3.25} = 146{,}000 \text{ psi}$$

channel

$$\sigma' = \frac{16 \times 10^6 \times .016}{3.25} = 78{,}700 \text{ psi}$$

stresses remaining in wire due to wrapping:

Dumbell:

wrap on 6.5"	146,000
unwrap from 7.0"	135,500
net stress	10,500 psi

Channel:

wrap on 6.5"	78,700
unwrap from 7.0"	73,000
net stress	5,700 psi

To keep total preload in wire below 50,000 psi:

Dumbell $50{,}000 - 10{,}500 = 39{,}500$ use $P \leq 200^{\#}$ as before

channel $50{,}000 - 5700 = 44{,}300$

$$44{,}300 = \frac{P}{A}$$

$$P = 44{,}300 \times .0037 = 165^{\#}$$

This assumes full axial load will remain in wire.

Recommend max $P = 200^{\#}$ for Dumbell & Channel

CURTISS - WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 27 OF SHEETS 28

ENGINE NO. Wire Wrap

JOB NO. 51792

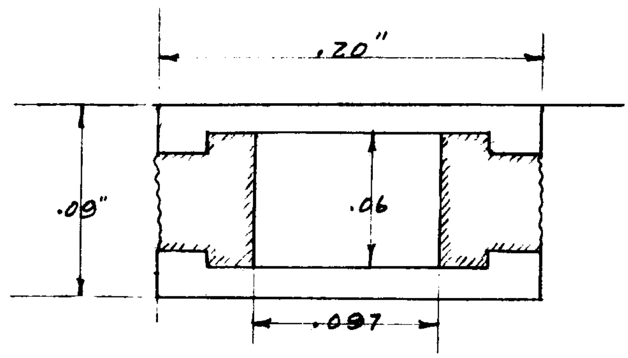
SUBJECT: End Taper on Dome Adapter Piece

WRITTEN BY D. Kanowsky

APPROVED BY WBG

DATE 3/8/60

RESULTS, SKETCHES & FORMULAS



Effective thickness of wire assembly:

Area in .20" length: $.09 \times .20 = .0180$

$- \; .097 \times .06 = \underline{.0058}$

$.0122$

Area per inch $= .0122 \times \frac{1}{.20} = .061$ "

Effective thickness $= .061$ "

use thickness at end of tricent taper: $\underline{\underline{t = .025''}}$

Thickness for yielding of tricent at 5000 psi pressure:

$\frac{pR}{t} = \sigma_y \qquad t = \frac{pR}{\sigma_y} \qquad \sigma_y = 220{,}000$ psi

$$t = \frac{5000 \times 3.25}{220{,}000} = .074 \sim \underline{\underline{.075}}$$

CURTISS - WRIGHT CORPORATION
WRIGHT AERONAUTICAL DIVISION

RECORD OF ANALYSIS

SHEET 28 OF SHEETS 28

ENGINE NO. Wire Wrap

JOB NO. 51792

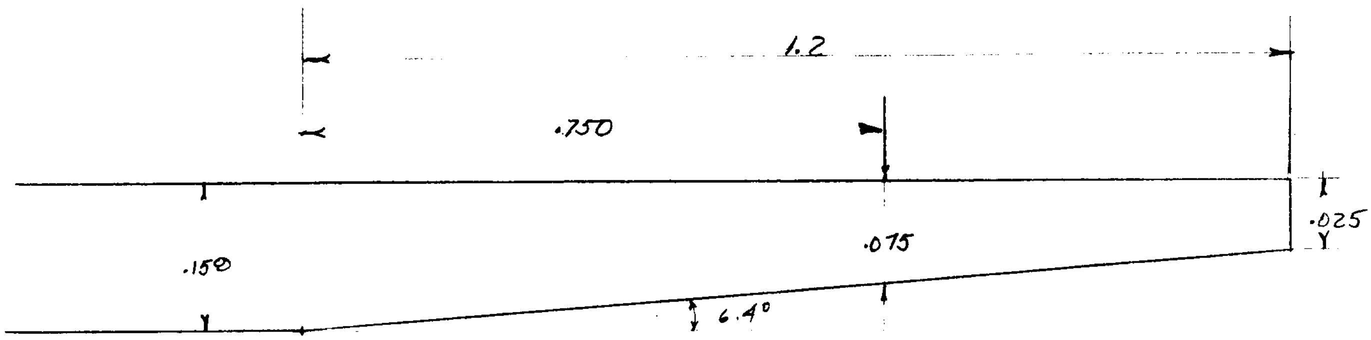
SUBJECT: End Taper on Dome Adapter Piece

WRITTEN BY D. Konowsky

APPROVED BY WBG

DATE 3/8/60

RESULTS, SKETCHES & FORMULAS



$$\frac{.075 - .025}{.159 - .075} \times .750 = .445$$

$$\frac{.159 - .025}{1.2} = \tan\alpha = \frac{.134}{1.2} = .1118$$

$$\alpha = 6.4^\circ$$

The .025 end thickness and .75 length were arbitrarily chosen. The adapter will yield from the .75 length to the .025 end, thus reducing the effects of the interlocking wire wrapped cylinder - adapter discontinuity.

Memo: Leprete to Lorsch 2/10/60

APPENDIX II

STRUCTURAL RIG TESTING PROCEDURE

1. Instrument the specimen as shown in Figure 16 and check.

2. Balance all gages. Take a zero and a calibration reading.

3. A combination of three loads is to be applied to the specimen for each reading of strain values. These are the tensile, the longitudinal clamping load from the torquing of the two 7/8 in. side bolts, and the transverse clamping load induced by torquing the two 1/4 in. top bolts. For each combination of pull load and transverse clamping load, three longitudinal clamping loads are applied.

   A typical cycle in applying the loads is as follows:

   (a) Torque 1/4 in. transverse clamping bolts to 4 in. lbs. Apply 4,650 lbs. tensile load to specimen and record strain readings. Release the load.

   (b) Using the same transverse clamping load as in step (a), apply 489 in. lbs. torque on the 7/8 in. longitudinal clamping bolts. Apply the same load as in step (a) and record the strain readings. Release the load. (c) repeat step (c) using 586 in. lbs. torque on the 7/8 in. longitudinal clamping bolts.

4. Tabulation of the test loads and the order of their application are as follows:

APPENDIX II (Continued)

Longitudinal Clamping Load (lbs.)		Equiv. (Approx.) 7/8 in Bolt Torque (in.lbs.)	Tensile Load (lbs.)	Trans. Clamp Load (lbs.)	Equiv. (Approx.) 1/4 in Bolt Torque (in.lbs.)
(a)	2360	391	4,650	81	4
(b)	2950	489			
(c)	3540	486			
(a)	3930	651	7,750	135	6
(b)	4910	813			
(c)	5880	974			
(a)	5490	909	10,850	189	9
(b)	6860	1136			
(c)	8230	1363			
(a)	7050	1167	13,950	243	11
(b)	8840	1464			
(c)	10600	1755			
(a)	8650	1432	17,050	297	14
(b)	10800	1799			
(c)	12820	2123			
(a)	10250	1697	20,150	351	16
(b)	12750	2111			
(c)	15400	2550			

APPENDIX III

B120VCA TITANIUM WIRE SPECIFICATION

1. ACKNOWLEDGEMENT: Vendor shall mention the specification number and its revision letter in all quotations and when acknowledging purchasing orders.

2. FORM: Coils of wire.

3. COMPOSITION:

		CHECK ANALYSIS Under Min.	or Over Max.
Vanadium	12.5-14.5	0.15	0.15
Chromium	10.00-12.00	0.15	0.15
Aluminum	3.0-4.0	0.40	0.40
Oxygen	0.15-Max.	-	-
Carbon	0.06-Max.	-	0.02
Nitrogren	0.05-Max.	-	0.02
Hydrogen	0.0100-Max.	-	.001
Other Elements	0.060-Max.	-	-
Iron	0.35-Max.	-	0.05
Titanium	balance	-	-

4. CONDITION:

4.1 Uniformly solution annealed after final draw.

4.2 Material shall be free from all surface and sub-surface defects.

4.3 No surface contamination or oxide film.

4.4 Wire shall be coil ground before final draw.

4.5 Wire shall contain no seams, nicks, kinks, bends, breaks, burrs, scratches, or marks due to grinding or drawing.

4.6 Wire surface must be clean and contain no foreign materials and imperfections which may adversely affect the processing or quality of finished articles.

APPENDIX III (Continued)

5. TOLERANCES: Unless otherwise specified, tolerances shall conform to the following:

Diameter	Nominal Inch	Tolerances, Inch Plus	Tolerances, Inch Minus
.130 -	.200	0.001	0.001
.121 -	.130	0.000	0.0005
	0.120	0.0005	0.0005

6. TENSILE PROPERTIES:

Tensile strength, psi	130,000 min.
Reduction in area, %	25 min.

7. REPORTS: Unless otherwise specified, the vendor of wire shall furnish with each shipment three copies of a report of the results of tests for chemical composition and tensile strength of each coil in the shipment. This report shall include the purchase order, heat number, material specification number, size, and quantity.

8. PACKAGING: Packaging shall be accomplished in such a manner as to insure that the wire, during shipment and storage, will be protected against mechanical injury.

9. APPROVAL: To assure adequate performance characteristics, wire shall be approved by purchaser before use, unless such approval be waived.

10. REJECTIONS: Material not conforming to this specification or to authorized modifications will be subjected to rejection.

CURTISS WRIGHT CORP-WRIGHT AERONAUTICAL DIV
WIRE WRAP ROCKET CASE DEVELOPMENT DEPT 8612
SCHEDULE NO 42
START DATE   EVALUATION DATE
2011960   02141961
OPEN SCHEDULE

MILESTONE ACTIVITY   ORIGINAL TARGET   CURRENT PREDICTION   DAYS LATE   EXPECTED TIME-WKS   VARIANCE
802000099   02141961   02141961   00.0   049.6   00.

	0800100001 0800100001	DEV OPT HEATTREAT FOR WIRE	112.00	8612	1/29/0 1/29/0	7/08/0 7/08/0	112. 112.0	4/15/0 12051960	54.	01.	1
	0800100005 0800100005	EFF OF SINGLE&DUPL AGING	87.00	8612	1/29/0 1/29/0	6/02/0 6/02/0	87. 87.0	4/15/0 12051960	54. , N	01.	2
	0800100010 0800100010	SELECT PLASTIC	35.00	8612	2/01/0 1/29/0	3/21/0 3/21/0	35. 35.0	3/21/0 6131960	35.	01.	3
	0800100020 0800100020	DEV ROLLING TECHNIQUES 0880100020	12.00	8612	3/08/0 3/04/0	3/23/0 3/22/0	12. 12.0	3/23/0 11231960	12.	01.	4
	0800100025 0800100025	METHODS DEVEL INSPECT WIRE 0800100020	27.00	8612	3/08/0 3/22/0	4/28/0 4/28/0	27. 27.0	5/05/0 1041961	43.	01.	5
	0800200001 0800200001	PROCURE ROLLS- 2 SHAPES	26.00	8612	1/29/0 1/29/0	3/17/0 3/08/0	26. 26.0	3/23/0 6011960	37.	01.	6
	0800200005 0800200005	PROCURE DIES-CHANNEL SHAPE	42.00	8612	1/29/0 1/29/0	3/30/0 3/30/0	42. 42.0	3/30/0 9261960	42.	01.	7
	0800200010 0800200010	PROC ROUND WIRE-2 VESSELS 0880200010	15.00	8612	2/24/0 2/24/0	3/16/0 3/16/0	15. 15.0	3/30/0 9261960	25.	01.	8
	0800200011 0800200011	PROC O RINGS MIL-G-5510 0880200050	25.00	8612	3/01/0 3/01/0	4/05/0 4/05/0	25. 25.0	5/16/0 1041961	53.	01.	9
	0800200012 0800200012	PROC LEATHER BACKUP RINGS 0880200050	28.00	8612	3/01/0 3/01/0	4/19/0 4/08/0	28. 28.0	5/16/0 1041961	53.	01.	10
AN104812	0800200013 0800200013	PROC BOLTS 0880200050	52.00	8612	3/01/0 3/01/0	5/12/0 5/12/0	52. 52.0	5/16/0 1041961	53.	01.	11
AN806-5S	0800200014 0800200014	PROC FITTINGS 0880200050	22.00	8612	3/01/0 3/01/0	3/31/0 3/31/0	22. 22.0	5/16/0 12281960	53.	01.	12
	0800200015 0800200015 0800200015	PROD SAMPLE TI WIRE-INTRLK 0800200001 0880200015	 5.00 5.00	8612	3/23/0 3/23/0	3/30/0 3/30/0	5. 5.0 5.0	3/30/0 6081960	25.	01.	13
AN929-5S	0800200016	PROC FITTINGS		8612	3/01/0	3/31/0	22.	5/16/0	53.		14

	0800200016	0880200050	22.00		3/01/0	3/31/0	22.0	1041961			01.	
				8420	3/31/0	4/14/0	10.	4/28/0	10.			15
AN 806 55	0800200017	RWK FITTINGS AN806-55			3/31/0	4/14/0	10.0	1121961			01.	
	0800200017	0800200014	10.00									
				8420	4/14/0	4/20/0	4.	5/12/0	10.			16
LS 25439 A1	0800200018	FAB PLUG & FITTING ASSY			4/14/0	4/20/0	4.0	1181961			01.	
	0800200018	0800200017	4.00									
	0800200019	PROD TI CH SAMPLE-10 FT		8612	4/14/0	6/25/0	50.	4/18/0	10.			17
	0800200019	0800200015	50.00		4/14/0	6/24/0	50.0	9261960			01.	
	0800200019	0800200021	50.00				50.0					
	0800200019	0880200019	50.00				50.0					
	0800200020	H.T.CH WIRE-DUMMY ARBOR		8612	9/21/0	9/21/0	.	5/16/0	5.	N		18
	0800200020	0800100001	.		9/23/0	9/23/0	.	12051960			01.	
	0800200020	0800100005	.				.					
	0800200020	0800200099	.				.					
	0800200021	PROC 2 NEW SETS ROLLS		8612	3/30/0	4/14/0	11.	4/11/0	9.			19
	0800200021	0800200015	11.00		3/30/0	4/14/0	11.0	6231960			01.	
	0800200022	MODIFICATION #3TI WIRE		8612		5/05/0	.0	4/26/0	8.	N		20
	0800200022	0800200019	.		6/24/0	6/24/0	.	9261960			01.	
6T 50507	0800200023	PROC 3 GND WHEEL HLD FIX		8612	3/28/0	4/18/0	15.0	4/18/0	15.			21
	0800200023	0880200023	15.00		3/28/0	4/18/0	15.0	10271960			01.	
	0800200025	TI I SAMPLE-10 FT		8612	4/14/0	8/16/0	71.	7/21/0	68.			22
	0800200025	0800200015	71.00		4/14/0	8/16/0	71.0	11011960			01.	
	0800200025	0800200021	71.00				71.0					
	0800200025	0880200019	71.00				71.0					
	0800200030	ROLL WIRE-I-DUMMY ARBOR		8612	8/16/0	9/16/0	22.	7/22/0	1.			23
	0800200030	0800200025	22.00		8/16/0	9/16/0	22.0	12051960			01.	
	0800200035	H.T.-I-WIRE-DUMMY ARBOR		8612	9/16/0	9/21/0	3.	8/19/0	5.	N		24
	0800200035	0800100001	3.00		9/16/0	9/21/0	3.0	12161960			01.	
	0800200035	0800200030	3.00				3.0					
	0800200099	ROLL WIRE-CH-DUMMY ARBOR		8612	6/24/0	9/23/0	48.	5/09/0	28.			25
	0800200099	0800200001	48.00		6/24/0	9/23/0	48.0	12051960			01.	
	0800200099	0800200005	48.00				48.0					
	0800200099	0800200010	48.00				48.0					
	0800200099	0800200015	48.00				48.0					
	0800200099	0800200019	48.00				48.0					
	0800200099	0800200022	48.00				48.0					
	0800200105	ROLL WIRE #1 VESSEL		8612	9/23/0	9/30/0	5.	9/19/0	11.			26
	0800200105	0800200030	5.00		9/23/0	9/30/0	5.0	12211960			01.	
	0800200105	0800200099	5.00				5.0					
	0800200110	HEAT TREAT WIRE #1 VESSEL		8612	9/30/0	10/12/0	8.	9/29/0	8.	N		27
					9/30/0	10/12/0		1041961			01.	

0800200110	0800200030	8.00				8.0				
0800200110	0800200099	8.00				8.0				
0800200110	0800200105	8.00				8.0				
0800200120	REPAIR HEAT TREAT FACIL		8612	9/19/0	11/01/0	31.	10/10/0	15.		28
0800200120	0888000005	31.00		9/19/0	11/01/0	31.0	12281960		01.	
0800200125	MFG I-BEAM #7 ROLL		8612	10/05/0	10/21/0	12.	10/17/0	8.		29
0800200125	0888000006	12.00		10/05/0	10/21/0	12.0	12051960		01.	
0800200130	MFG CHANNEL #4 ROLL		8612	10/05/0	10/21/0	12.	10/17/0	8.		30
0800200130	0888000006	12.00		10/05/0	10/21/0	12.0	11281960		01.	
0800200132	MFG SIDE CHANNL FORM ROLLS		8612	10/21/0	10/28/0	5.	10/28/0	5.		31
0800200132	0800200130	5.00		10/21/0	10/28/0	5.0	12051960		01.	
0800200135	EVAL ADD TEFLN&PLASTC RESN		8612	10/14/0	11/10/0	18.	11/01/0	12.		32
0800200135	0800400090	18.00		10/14/0	11/10/0	18.0	1241961		01.	
0800200140	DESIGN CYLINDRICAL GRIPS		8321	10/24/0	10/28/0	4.	10/28/0	4.		33
0800200140	0888000007	4.00		10/24/0	10/28/0	4.0	12141960		01.	
0800200142	SPRAY VES #1		8612	11/17/0	11/30/0	8.	11/30/0	8.		34
0800200142	0888000008	8.00		11/17/0	11/30/0	8.0	1181961		01.	
0800200145	MFG CYLINDRICAL GRIPS		8420	10/28/0	12/13/0	30.	11/21/0	15.		35
0800200145	0800200140	30.00		10/28/0	12/13/0	30.0	1271961		01.	
0800200148	MFG STRUCTURAL RIG		8420	11/17/0	1/18/1	41.	12/19/0	21.		36
0800200148	0888000008	41.00		11/17/0	1/18/1	41.0	-1181961		01.	
0800200150	TEST WIRE		8612	12/13/0	1/05/1	15.	12/13/0	15.		37
0800200150	0800200145	15.00		12/13/0	1/05/1	15.0	2171961		01.	
0800200155	MFG NEW ROLL DIE FOR CH/NL		8612	12/19/0	1/03/1	9.	12/23/0	4.		38
0800200155	0888000009	9.00		12/19/0	1/03/1	9.0	2021961		01.	
0800300001	PRODUCE WIRE FOR VES NO.2		8612	10/28/0	11/22/0	16.	6/30/0	33.		39
0800300001	0800200020	16.00		10/28/0	11/22/0	16.0	12281960		01.	
0800300001	0800200030	16.00				16.0				
0800300001	0800200099	16.00				16.0				
0800300001	0800200125	16.00				16.0				
0800300001	0800200130	16.00				16.0				
0800300001	0800200132	16.00				16.0				
0800300001	0800400001	16.00				16.0				
0800300003	HEAT TREAT WIRE VES #2		8612		11/15/0	.	11/07/0	5.	N	40
0800300003	0800200120	.		11/22/0	11/22/0	.	12281960		01.	
0800300003	0800300001	.				.				
0800300300	ROLL WIRE VES #3		8612	1/03/1	1/18/1	11.	11/07/0	5.		41
0800300300	0800300001	11.00		1/03/1	1/18/1	11.0	2171961		01.	
0800300300	0800200155	11.00				11.0				

0800400001	METH DEVEL-PLASTIC APPL	8612	3/21/0	4/07/0	13.	5/10/0	36.	N	42
0800400001	0800100010 13.00		3/21/0	4/07/0	13.0	12051960		01.	
0800400070	EVALUATE SOLDER	8612	6/20/0	9/14/0	45.	8/19/0	28.		43
0800400070	0800400099 45.00		6/20/0	9/14/0	45.0	2171961		01.	
0800400080	EVAL ULTRASONIC WELDING	8612	6/20/0	8/24/0	31.	8/19/0	28.		44
0800400080	0800400099 31.00		6/20/0	8/24/0	31.0	1041961		01.	
0800400090	EVALUATE TEFLON SAMPLES	8612	6/20/0	10/14/0	67.	9/23/0	54.		45
0800400090	0800400099 67.00		6/20/0	10/14/0	67.0	12281960		01.	
0800400099	EVAL APPLICATION OF PLSTIC	8612	4/01/0	6/20/0	55.	5/02/0	21.		46
0800400099	0800100010 55.00		4/01/0	6/20/0	55.0	9211960		01.	
0800400099	0880400099 55.00				55.0				
0800500001	STRESS ANAL-CHANNEL WIRE	8325	1/29/0	2/19/0	20.	2/19/0	20.		47
0800500001	15.00		1/29/0	2/19/0	15.0	9021960		01.	
0800500004	STRESS ANAL-DUMBBELL WIRE	8325	1/29/0	2/19/0	20.	2/19/0	20.		48
0800500004	15.00		1/29/0	2/19/0	15.0	9021960		01.	
0800500008	STRESS ANAL-ADAPTERS	8325	2/08/0	3/07/0	19.	3/07/0	19.		49
0800500008	0880500008 19.00		2/08/0	3/07/0	19.0	9021960		01.	
0800500010	STRESS ANAL-PIN NO 1	8325	2/08/0	3/07/0	19.	3/07/0	19.		50
0800500010	0880500010 19.00		2/08/0	3/07/0	19.0	9021960		01.	
0800500012	STRESS ANAL-PIN NO 2	8325	2/08/0	3/07/0	19.	3/07/0	19.		51
0800500012	0880500012 19.00		2/08/0	3/07/0	19.0	9021960		01.	
0800500014	STRESS ANAL-PIN NO 3	8325	2/08/0	3/07/0	19.	3/07/0	19.		52
0800500014	0880500014 19.00		2/08/0	3/07/0	19.0	9021960		01.	
0800500030	DESIGN CHANNEL WIRE	8321	1/29/0	3/07/0	25.	3/07/0	25.		53
0800500030	25.00		1/29/0	3/07/0	25.0	9021960		01.	
0800500032	DESIGN DUMBBELL WIRE	8321	1/29/0	3/07/0	25.	3/07/0	25.		54
0800500032	25.00		1/29/0	3/07/0	25.0	9021960		01.	
0800500034	DESIGN ADAPTERS	8321	1/29/0	3/07/0	25.	3/07/0	25.		55
0800500034	25.00		1/29/0	3/07/0	25.0	9021960		01.	
0800500035	RELEASE DESIGN	8612	3/07/0	3/07/0	.	3/07/0	.		56
0800500035	0800500099 .00		3/07/0	3/07/0	.0	9021960		01.	
0800500036	DESIGN STAKING PIN NO 1	8321	1/29/0	3/07/0	25.	3/07/0	25.		57
0800500036	25.00		1/29/0	3/07/0	25.0	9021960		01.	
0800500038	DESIGN STAKING PIN NO 2	8321	1/29/0	3/07/0	25.	3/07/0	25.		58
0800500038	25.00		1/29/0	3/07/0	25.0	9021960		01.	
0800500040	DESIGN STAKING PIN NO 3	8321	1/29/0	3/07/0	25.	3/07/0	25.		59

	0800500040		25.00		1/29/0	3/07/0	25.0	9021960		01.	
	0800500099	COMPLETE DES&STRESS ANAL		8612	3/07/0	3/07/0	.	3/07/0	.	M	60
	0800500C99	0800500001	.00		3/07/0	3/07/0	.0	9021960		01.	
	0800500099	0800500004	.00				.0				
	0800500099	0800500008	.00				.0				
	0800500099	0800500010	.00				.0				
	0800500099	0800500012	.00				.0				
	0800500099	0800500014	.00				.0				
	0800500099	0800500030	.00				.0				
	0800500099	0800500032	.00				.0				
	0800500099	0800500034	.00				.0				
	0800500099	0800500036	.00				.0				
	0800500099	0800500038	.00				.0				
	0800500099	0800500040	.00				.0				
6150SAE	0800510001	PROC BOLTS RND HD DR STUD		8612	3/07/0	3/31/0	18.	5/13/0	50.		61
	0800510001	0800500035	18.00		3/07/0	3/31/0	18.0	1041961		01.	
6150SAE	0800510002	PROC BOLTS GROOV PIN TYPE3		8612	3/07/0	3/31/0	18.	5/13/0	50.		62
	0800510002	0800500035	18.00		3/07/0	3/31/0	18.0	1041961		01.	
	0800600001	EVAL MACH METHODS-ADAPTERS		842C	3/01/0	3/15/0	10.	3/15/0	10.		63
	0800600001	0880600001	10.00		3/01/0	3/15/0	10.0	9161960		01.	
	0800600005	METHODS DEVELOP-ADAPTERS		8420	3/15/0	3/30/0	11.	3/30/0	11.		64
	0800600005	0800600001	11.00		3/15/0	3/30/0	11.0	10031960		01.	
	0800700001	PROC ADAPTER MATERIAL		8612	1/29/0	3/07/0	25.	3/07/0	25.		65
	0800700001		25.00		1/29/0	3/07/0	25.0	10271960		01.	
	0800700002	PROC ADDIT ADAPTER MATL		8612	3/15/0	5/02/0	34.	5/03/0	35.		66
	0800700002	0800600001	34.00		3/15/0	5/02/0	34.0	1041961		01.	
6T 60925	0800700004	TOOL DESIGN MANDREL		8420	3/14/0	3/23/0	7.	3/21/0	10.		67
	0800700004	0800700021	7.00		3/14/0	3/23/0	7.0	9261960		01.	
	0800700006	TOOL SHEETS MANDREL		8420	3/23/0	3/23/0	.	3/28/0	5.		68
	0800700006	0800700004	.00		3/23/0	3/23/0	.0	9261960		01.	
	0800700010	FABRICATE MANDREL		8420	3/23/0	6/13/0	57.	5/02/0	25.		69
	0800700010	0800700004	57.00		3/23/0	6/13/0	57.0	12161960		01.	
	0800700010	0800700006	57.00				57.0				
	0800700010	0880700010	57.00				57.0				
6T 60926	0800700012	TOOL DESIGN END ADAPTERS		8420	3/14/0	3/25/0	9.	3/21/0	10.		70
	0800700012	0800700021	9.00		3/14/0	3/25/0	9.0	9301960		01.	
	0800700014	TOOL SHEETS END ADAPTERS		8420	3/25/0	3/28/0	1.	3/28/0	5.		71
	0800700014	0800700012	1.00		3/25/0	3/28/0	1.0	10031960		01.	
	0800700018	TOOL FAB END ADAPTERS		8420	3/28/0	4/25/0	18.	4/17/0	15.		,2
					3/30/0	4/25/0		10271960		01.	

		0800700018	0800600005	18.00				18.0				
		0800700018	0800700014	18.00				18.0				
		0800700018	0880700018	18.00				18.0				
LS 25439	7	0800700020	PART SHEETS ADAPTERS		8420	3/11/0	3/22/0	7.	3/25/0	10.		73
		0800700020	0800500099	7.00		3/11/0	3/22/0	7.0	10271960		01.	
		0800700020	0880700020	7.00				7.0				
		0800700021	E033177 RELEASE DESIGN		8241	3/09/0	3/11/0	3.	3/11/0	3.		74
		0800700021	0800500035	5.00		3/07/0	3/14/0	5.0	9121960		01.	
LS 25439	7	0800700022	FABRICATE ADAPTERS		8420	4/25/0	6/28/0	45.	5/09/0	15.		75
		0800700022	0800200023	45.00		4/25/0	6/28/0	45.0	1041961		01.	
		0800700022	0800500035	45.00				45.0				
		0800700022	0800700001	45.00				45.0				
		0800700022	0800700018	45.00				45.0				
		0800700022	0800700020	45.00				45.0				
		0800700022	0800700021	45.00				45.0				
		0800700022	0880700022	45.00				45.0				
DA 32360		0800700030	SHEETS-DUMMY ARBOR		8420	3 18 0	3 24 0	4.	3 24 0	4.		76
		0800700030	0880700030	4.00		3/18/0	3/24/0	4.0	6151960		01.	
DA 32360		0800700035	FABR-DUMMY ARBOR		8420	3 24 0	7 18 0	80.	3 29 0	5.		77
		0800700035	0800700030	80.00		3/24/0	7/18/0	80.0	10281960		01.	
		0800800001	METHODS DEVELOPMT STAKING		8420	3/30/0	4/11/0	8.	4/11/0	8.		78
		0800800001	0800500099	8.00		3/30/0	4/11/0	8.0	12161960		01.	
		0800800001	0880800001	8.00				8.0				
		0800800005	METHODS DEVELOPMT WRAPPING		8420	7/18/0	10/10/0	44.	5/16/0	33.		79
		0800800005	0800200019	44.00		7/18/0	10/10/0	44.0	1041961		01.	
		0800800005	0800500099	44.00				44.0				
		0800800005	0800700035	44.00				44.0				
		0800800005	0880800001	44.00				44.0				
6T 60924		0800800010	TOOL DESIGN WRAPPING MACH		8420	3/14/0	4/13/0	22.	3/28/0	15.		80
		0800800010	0800700021	22.00		3/14/0	4/13/0	22.0	10121960		01.	
		0800800015	TOOL SHEETS WRAPPING MACH		8420	4/13/0	4/18/0	3.	4/01/0	4.		81
		0800800015	0800800010	3.00		4/13/0	4/18/0	3.0	10171960		01.	
		0800800018	TOOL FAB WRAPPING MACH		8420	4/18/0	6/16/0	42.	5/09/0	26.		82
		0800800018	0800800015	42.00		4/18/0	6/16/0	42.0	12161960		01.	
		0800800020	WRAP & STAKE CYL SAMPLE		8420	9/23/0	10/10/0	11.	5/16/0	5.		83
		0800800020	0800200020	11.00		9/23/0	10/10/0	11.0	1041961		01.	
		0800800020	0800200035	11.00				11.0				
		0800800020	0800200099	11.00				11.0				
		0800800020	0800400099	11.00				11.0				
		0800800020	0800700010	11.00				11.0				
		0800800020	0800700018	11.00				11.0				
		0800800020	0800700035	11.00				11.0				

	0800800020	0800800001	11.00				11.0				
	0800800020	0800800018	11.00				11.0				
	0800800020	0800800030	11.00				11.0				
	0800800020	0800800040	11.00				11.0				
	0800800020	0800800045	11.00				11.0				
				8420	4/18/0	4/21/0	3.	4/21/0	8.		84
6T 60982	0800800025	DESIGN ROLLERS			4/18/0	4/21/0	3.0	10271960		01.	
	0800800025	0800800015	3.00								
				8420	4/21/0	6/09/0	34.	5/17/0	18.		85
6T 60982	0800800030	PROCURE ROLLERS			4/21/0	6/09/0	34.0	12161960		01.	
	0800800030	0800800025	34.00								
				8420	4/13/0	4/25/0	8.	4/22/0	7.		86
6T 60988	0800800035	DESIGN REEL EQUIP			4/13/0	4/25/0	8.0	10241960		01.	
	0800800035	0800800010	8.00								
				8420	4/25/0	6/16/0	37.	5/17/0	17.		87
6T 60988	0800800040	FAB REEL EQUIP			4/25/0	6/16/0	37.0	12161960		01.	
	0800800040	0800800035	37.00								
				8612	7/05/0	8/15/0	14.	7/21/0	13.		88
	0800800042	FRICTION TEST-TI WIRE			7/05/0	8/15/0	14.0	11111960		01.	
	0800800042	0888000001	14.00								
				8612	8/16/0	9/20/0	24.	7/18/0	11.		89
	0800800045	DET COMPR LD TO LOCK SAMPL			8/16/0	9/20/0	24.0	12161960		01.	
	0800800045	0800200019	24.00				24.0				
	0800800045	0800200025	24.00				24.0				
	0800800045	0800800042	24.00				24.0				
	0800800045	0880800045	24.00								
				8413	7/18/0	9/14/0	27.	9/06/0	21.	N	90
	0800800050	PROCURE LIN POT			7/15/0	9/14/0	27.0	1041961		01.	
	0800800050	0888000003	27.00								
				8413	9/06/0	9/23/0	13.	9/09/0	3.		91
	0800800055	DES CONCNTRCTY MEAS DEV			9/06/0	9/23/0	13.0	12201960		01.	
	0800800055	0888000004	13.00								
				8413	9/23/0	10/03/0	6.	9/16/0	5.		92
	0800800060	FAB CONCNTRCTY MEAS DEV			9/23/0	10/03/0	6.0	12291960		01.	
	0800800060	0800800055	6.00								
				8413	10/03/0	10/06/0	3.	9/20/0	2.		93
	0800800065	MNT CONCNTRCTY MEAS DEV			10/03/0	10/06/0	3.0	1041961		01.	
	0800800065	0800800060	3.00								
				8420	10/12/0	10/19/0	5.	6/20/0	24.	M	94
	0800900001	WRAP VESSEL NO 1			10/12/0	10/19/0	5.0	1111961		01.	
	0800900001	0800100025	5.00				5.0				
	0800900001	0800200011	5.00				5.0				
	0800900001	0800200012	5.00				5.0				
	0800900001	0800200013	5.00				5.0				
	0800900001	0800200014	5.00				5.0				
	0800900001	0800200016	5.00				5.0				
	0800900001	0800200020	5.00				5.0				
	0800900001	0800200110	5.00				5.0				
	0800900001	0800400080	5.00				5.0				
	0800900001	0800510001	5.00				5.0				
	0800900001	0800510002	5.00				5.0				
	0800900001	0800700002	5.00				5.0				
	0800900001	0800700010	5.00								

0800900001	0800700018	5.00				5.0				
0800900001	0800700022	5.00				5.0				
0800900001	0800800001	5.00				5.0				
0800900001	0800800005	5.00				5.0				
0800900001	0800800020	5.00				5.0				
0800900001	0800800050	5.00				5.0				
0800900001	0800800065	5.00				5.0				
0800900002	FAB JACK-PISTON RIG		8423	7/11/0	9/09/0	28.	11/02/0	68.		95
0800900002	0888000002	28.00		7/11/0	9/09/0	28.0	1181961		01.	
0800900003	FAB SEGMENTS-PISTON RIG		8423	7/11/0	9/12/0	29.	11/02/0	68.		96
0800900003	0888000002	29.00		7/11/0	9/12/0	29.0	1181961		01.	
0800900005	INSP&TEFLON SPRAY 1ST VES		8612		10/11/0	.	6/23/0	3.	N	97
0800900005	0800900001	.		10/19/0	10/19/0	.	1181961		01.	
0800900005	0800900002	.				.				
0800900005	0800900003	.				.				
0800900005	0800400090	.				.				
0800900010	WRAP ARBOR,VESSEL #2 WIRE		8420	11/22/0	11/30/0	5.	11/17/0	5.		98
0800900010	0800300003	5.00		11/22/0	11/30/0	5.0	1051961		01.	
0800900011	2ND WRAP ARBOR VESSEL#2 WI		8420	11/30/0	12/06/0	4.	12/06/0	4.		99
0800900011	0800900010	4.00		11/30/0	12/06/0	4.0	1111961		01.	
0801000001	WRAP VESSEL NO 2		8420	12/06/0	12/13/0	5.	7/15/0	10.		100
0801000001	0800300001	5.00		12/06/0	12/13/0	5.0	1181961		01.	
0801000001	0800300003	5.00				5.0				
0801000001	0800700010	5.00				5.0				
0801000001	0800700018	5.00				5.0				
0801000001	0800700022	5.00				5.0				
0801000001	0800800001	5.00				5.0				
0801000001	0800800005	5.00				5.0				
0801000001	0800900001	5.00				5.0				
0801000001	0800900011	5.00				5.0				
0801000001	0881000001	5.00				5.0				
0801000005	INSPECT&VINYL SPRAY VES 2		8612	12/13/0	12/23/0	8.	10/11/0	6.		101
0801000005	0800200135	8.00		12/13/0	12/23/0	8.0	2031961		01.	
0801000005	0801000001	8.00				8.0				
0801100001	INSTRUMENT VESSEL NO 1		8413		10/11/0	.	6/24/0	1.	N	102
0801100001	0800200018	.		10/19/0	10/19/0	.	1181961		01.	
0801100001	0800900001	.				.				
0801100001	0800900005	.				.				
0801100005	TEST VESSEL NO 1		8413		10/11/0	.	6/28/0	1.	N	103
0801100005	0801100001	.		10/19/0	10/19/0	.	1181961		01.	
0801100010	DATA REDUCTION VESSEL NO 1		8413		10/11/0	.	6/29/0	1.	N	104
0801100010	0801100005	.		10/19/0	10/19/0	.	1181961		01.	
0801100015	EVALUATE TEST DATA V NO 1		8325		10/11/0	.	7/06/0	5.	N	105

0801100015	0801100010	•		10/19/0	10/19/0	•	1181961		01•	
0801200001	INSTRUMENT VESSEL NO 2		8413	12/23/0	12/29/0	3•	7/21/0	1•		106
0801200001	0801000001	3.00		12/23/0	12/29/0	3.0	2081961		01•	
0801200001	0801000005	3.00				3.0				
0801200001	0801100015	3.00				3.0				
0801200005	TEST VESSEL NO 2		8413	12/29/0	1/10/1	7•	7/22/0	1•		107
0801200005	0801200001	7.00		12/29/0	1/10/1	7.0	2171961		01•	
0801300010	MONTHLY REPORT NO. 1		8612	7/15/0	7/22/0	5•	7/22/0	6•		108
0801300010	0888000003	5.00		7/15/0	7/22/0	5.0	9301960		01•	
0801300020	MONTHLY REPORT NO. 2		8612	7/22/0	8/31/0	13•	8/22/0	6•		109
0801300020	0801300010	13.00		7/22/0	8/31/0	13.0	10191960		01•	
0801300030	MONTHLY REPORT NO. 3		8612	8/31/0	9/30/0	21•	9/22/0	22•		110
0801300030	0801300020	21.00		8/31/0	9/30/0	21.0	11181960		01•	
0802000040	COMPILE REPORT NO 4 INFO		8612	9/30/0	10/24/0	16•	10/21/0	21•		111
0802000040	0801300030	16.00		9/30/0	10/24/0	16.0	12131960		01•	
0802000045	ISSUE MONTHLY REPORT NO 4		8612	10/24/0	10/31/0	5•	10/31/0	5•		112
0802000045	0802000040	5.00		10/24/0	10/31/0	5.0	12201960		01•	
0802000050	COMPILE REPORT NO 5 INFO		8612	10/31/0	11/23/0	16•	11/22/0	21•		113
0802000050	0802000045	16.00		10/31/0	11/23/0	16.0	1131961		01•	
0802000055	ISSUE MONTHLY REPORT NO 5		8612	11/23/0	11/30/0	4•	11/30/0	4•		114
0802000055	0802000050	4.00		11/23/0	11/30/0	4.0	1191961		01•	
0802000060	COMPILE REPORT NO 6 INFO		8612	11/30/0	12/23/0	17•	12/22/0	21•		115
0802000060	0802000055	17.00		11/30/0	12/23/0	17.0	2131961		01•	
0802000065	ISSUE MONTHLY REPORT NO 6		8612	12/23/0	12/30/0	4•	12/30/0	4•		116
0802000065	0802000060	4.00		12/23/0	12/30/0	4.0	2171961		01•	
0802000068	TEST TITAN•MIN•35-MIN•65 F		8612	1/03/1	1/17/1	10•	1/17/1	10•		117
0802000068	0888000010	10.00		1/03/1	1/17/1	10.0	1181961		01•	
0802000099	FINAL REPORT		8612	1/18/1	2/14/1	19•	10/04/0	35•	M	118
0802000099	0800100001	19.00		1/18/1	2/14/1	19.0	-2141961		01•	
0802000099	0800100005	19.00				19.0				
0802000099	0800100010	19.00				19.0				
0802000099	0800200142	19.00				19.0				
0802000099	0800200148	19.00				19.0				
0802000099	0800200099	19.00				19.0				
0802000099	0800300001	19.00				19.0				
0802000099	0800400099	19.00				19.0				
0802000099	0800500099	19.00				19.0				
0802000099	0800900001	19.00				19.0				
0802000099	0800900005	19.00				19.0				
0802000099	0801000001	19.00				19.0				

					19.0				
0802000099	0801100015	19.00			19.0				
0802000099	0802000068	19.00							
				/ /	24.		24.		119
0880100020	DUMMY JOB 1-20		1/29/0	3/04/0	24.0	11041960		01.	
0880100020		24.00							
				/ /	17.		17.		120
0880200010	DUMMY JOB 2-10		1/29/0	2/24/0	17.0	9021960		01.	
0880200010		17.00							
				/ /	37.		17.		121
0880200015	DUMMY JOB 2-15		1/29/0	3/23/0	37.0	6011960		01.	
0880200015		37.00							
			2/01/0	4/04/0	45.	4/04/0	45.		122
0880200019	DUMMY JOB 2-19		1/29/0	4/04/0	45.0	6231960		01.	
0880200019		45.00							
			1/29/0	3/28/0	40.0	3/28/0	40.		123
0880200023	DUMMY JOB NO. 2-23		1/29/0	3/28/0	40.0	10061960		01.	
0880200023		40.00							
				/ /	21.		21.		124
0880200050	DUMMY JOB 2-50		1/29/0	3/01/0	21.0	10181960		01.	
0880200050		21.00							
				/ /	.		44.		125
0880400099	DUMMY JOB 4-99		1/29/0	4/01/0	44.0	6131960		01.	
0880400099		44.00							
				/ /	6.		6.		126
0880500008	DUMMY JOB 5-08		1/29/0	2/08/0	6.0	7181960		01.	
0880500008		6.00							
				/ /	6.		6.		127
0880500010	DUMMY JOB 5-10		1/29/0	2/08/0	6.0	7181960		01.	
0880500010		6.00							
				/ /	6.		6.		128
0880500012	DUMMY JOB 5-12		1/29/0	2/08/0	6.0	7181960		01.	
0880500012		6.00							
				/ /	6.		6.		129
0880500014	DUMMY JOB 5-14		1/29/0	2/08/0	6.0	7181960		01.	
0880500014		6.00							
				/ /	21.		21.		130
0880600001	DUMMY JOB 6-01		1/29/0	3/01/0	21.0	9011960		01.	
0880600001		21.00							
				/ /	35.		35.		131
0880700010	DUMMY JOB 7-10		1/29/0	3/21/0	35.0	9261960		01.	
0880700010		35.00							
				/ /	.		42.		132
0880700018	DUMMY JOB 7-18		1/29/0	3/30/0	42.0	10031960		01.	
0880700018		42.00							
				/ /	29.		29.		133
0880700020	DUMMY JOB 7-20		1/29/0	3/11/0	29.0	10181960		01.	
0880700020		29.00							
				/ /	35.		35.		134
0880700022	DUMMY JOB 7-22		1/29/0	3/21/0	35.0	10271960		01.	
0880700022		35.00							
				/ /	34.		34.		135
0880700030	DUMMY JOB 7-30		1/29/0	3/18/0		6091960		01.	

0880700030		34.00				34.0		42.		136
					/ /	•				
0880800001	DUMMY JOB 8-01			1/29/0	3/30/0	42.0	10281960		01.	
0880800001		42.00								
				2/01/0	7/01/0	108.	7/01/0	108.		137
0880800045	DUMMY JOB			1/29/0	7/01/0	108.0	11111960		01.	
0880800045		108.00								
					6/30/0	107.		107.		138
0881000001	DUMMY JOB 10-1			1/29/0	6/30/0	107.0	1111961		01.	
0881000001		107.00								
				1/29/0	7/05/0	109.	7/05/0	109.		139
0888000001	DUMMY JOB			1/29/0	7/05/0	109.0	10211960		01.	
0888000001		109.00								
				1/29/0	7/11/0	113.	7/11/0	113.		140
0888000002	DUMMY JOB			1/29/0	7/11/0	113.0	12061960		01.	
0888000002		113.00								
				1/29/0	7/15/0	117.	7/15/0	117.		141
0888000003	DUMMY JOB			1/29/0	7/15/0	117.0	9231960		01.	
0888000003		117.00								
				1/29/0	9/06/0	138.	9/06/0	138.		142
0888000004	DUMMY JOB			1/29/0	9/06/0	138.0	12011960		01.	
0888000004		138.00								
				1/29/0	9/19/0	147.	9/19/0	147.		143
0888000005	DUMMY JOB			1/29/0	9/19/0	147.0	11111960		01.	
0888000005		147.00								
				1/29/0	10/05/0	159.	10/05/0	159.		144
0888000006	DUMMY JOB			1/29/0	10/05/0	159.0	11091960		01.	
0888000006		159.00								
				1/29/0	10/24/0	172.	10/24/0	172.		145
0888000007	DUMMY JOB			1/29/0	10/24/0	172.0	12081960		01.	
0888000007		172.00								
				1/29/0	11/17/0	189.	11/17/0	189.		146
0888000008	DUMMY JOB			1/29/0	11/17/0	189.0	-11171960		01.	
0888000008		189.00								
			8612	1/29/0	12/19/0	210.	12/19/0	210.		147
0888000009	DUMMY JOB			1/29/0	12/19/0	210.0	1201961		01.	
0888000009		210.00								
			8612	1/29/0	1/03/1	219.	1/03/1	219.		148
0888000010	DUMMY JOB			1/29/0	1/03/1	219.0	1041961		01.	
0888000010		219.00								
				2/14/1	2/14/1	•		•		149
9999999999	DUMMY END JOB FOR PROJECT			2/14/1	2/14/1	•	-2141961		01.	
9999999999	0800200150	•				•				
9999999999	0800300300	•				•				
9999999999	0800400070	•				•				
9999999999	0801000001	•				•				
9999999999	0801200005	•				•				
9999999999	0802000065	•				•				
9999999999	0802000099	•				•				

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